THE PROVINCIAL WATER QUALITY MONITORING NETWORK IN NORTHWESTERN ONTARIO:

DATA SUMMARY 1968 TO 1990

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THE PROVINCIAL WATER QUALITY MONITORING NETWORK
IN NORTHWESTERN ONTARIO:
DATA SUMMARY 1968 TO 1990

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Ontario Ministry of the Environment

APRIL 1992

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Executive Summary

The Provincial Water Quality Monitoring Network in Northwestern Ontario consists of 51 stations established since 1968 to monitor surface water quality in rivers and creeks throughout the region. Stations were selected to represent background conditions and impacts of industrial or urban sources. Sampling locations near the mouths of major tributaries to Lake Superior monitor loadings of major contaminants to the lake. Major sources of contamination being monitored were mining activities, the pulp and paper industry and waste water treatment plants.

The information summarized in this report is organized by major watershed, moving from east to west across the region. The characteristics of each station are described in terms of location, activities that affect water quality (i.e. Abatement Histories) and trends observed in key parameters.

Water quality is determined in terms of conventional parameters, bacteria and metals, with as many as 40 tests per station. Chlorinated organic compounds are not part of this data set but have been the subject of more specific studies. The tables, text and figures that summarize the data highlight specific parameters of concern.

Water quality data on which this report is based may be obtained from the Chief of Water Resources, Northwestern Region, Ontario Ministry of the Environment, P.O. Box 5000, 435 James Street South, Thunder Bay, Ontario, P7C 5G6, Ph. 807-475-1711, FAX 807-475-1754.

Sample collection and analysis over this extended period generated a sizeable quantity of information. Due the enormity and complexity of this data set, cautions regarding its collation and interpretation are necessary. The report identifies the strengths and limitations of the data and of the summaries and interpretations given. The water quality summaries are indicative rather than definitive. They indicate changes and likely trends, however, additional studies are required for definitive results.

Boxplots displaying data graphically summarize the large amount of information in a concise, representative manner. A section is devoted to the explanation of boxplot use and interpretation.

Surface Water Quality

Water quality conditions across the region are described under four categories: background conditions, improvements in water quality, rivers where water quality has become degraded through time, and those where it has remained impaired.

Background Conditions

Background conditions are variable across the region. Table A summarizes typical ranges of values for a variety of parameters in both the Lake Superior and Winnipeg River drainage basins.

Some parameters, particularly those such as conductivity that are related to solutes, seem to show long-term fluctuations that may relate to precipitation and/stream discharges.

Metal levels in areas with no known point sources showed several different patterns, depending on the individual metal, and on the geographical location. Several metals became undetectable in the late 1980's at several locations. In contrast, mercury was detected more frequently in several rivers on the north shore of Lake Superior in 1988/89 and on the Kaministiquia River in Thunder Bay in 1989.

Improved water quality

Improvements in water quality at stations that monitor the affects of industrial or urban inputs are usually associated with improvements in pollution abatement. Other significant changes in water quality are attributed to removal of point sources from the drainage basin and, in the case of phosphorus, to reductions in non-point sources as well.

Improvements are noted in some parameters downstream from pulp and paper mills across the region. Most of these improvements disappeared during low flows in recent dry years.

Metal levels declined on most rivers during the 1970's and 1980's; this may reflect analytical improvements as well as improved water quality. Declines in mercury in the early to mid 1980's occurred after the decommissioning of chlor-alkali plants.

Phosphorus levels have declined since the early 1970's on the Rainy and Wabigoon Rivers, the Chukuni River and in Red Lake. This reflects reduced inputs from urban sources and cottages.

Other major improvements resulted from the removal of the waste water treatment plant on the McIntyre River in Thunder Bay and the closure of the Griffith Mine near Ear Falls.

Persistent Problems/Deteriorating Water Quality

Water quality problems arose when large volumes of effluent were discharged into receiving waters with small flows, such as Blackbird Creek, or when flows were decreased due to drought conditions. Low flows occurred across the region in 1987, 1988.

Water quality on Hayward Creek and Balmer Creek deteriorated over the period of record. Serious impairments persist on Rudder Creek, Fox Creek, and in the upper reaches of the Black River downstream from Mose Lake.

Comment

The extensive record of this sampling network has provided a valuable archive of baseline conditions. They also offer the potential for defining temporal and spatial trends resulting from natural processes and aerial deposition, through further analysis. Such data are essential in assessing the impacts of current and future urban and industrial development.

Table A Ranges of long term median values for typical and polluted rivers in the Lake Superior and Winnipeg River drainage basins (all parameters are in mg/ℓ except pH and conductivity).

Parameter	Lake Superior Drainage		Winnipeg River Drainage		
	Typical	Polluted (extreme values)	Typical	Polluted (extreme values)	Provincial Water Quality Objective
Alkalinity	10-100	21/119	19-49	66	less than 25% change
Biological Oxygen Demand	0.6-1.4	180	0.7-2.3	9.2	-
Chlorides	<-20	272	1.0-2.3	40.5	-
Conductivity (µ Siemens)	73-264	1425	54-117	505	-
Hardness	35-124	345	22-54	150	-
pH	7.4-8.0	---	7.3-7.7	---	6.5-8.5
Sulphates	2-12	379	3.0-6.0	74.0	-
Solids - suspended	1-60	90	3-5	15	-
Solids - Total dissolved	100-180	1380	55-90	360	-
Total Phosphorus	0.008-0.037	0.93	0.018-0.032	0.140	0.03
Ammonia	0.02-0.06	3.9	0.02-0.03	1.3	0.02 (un-ionized)
Nitrites	0.002-0.005	0.130	0.003-0.006	2.7	-
Nitrates	0.006-0.05	6.05	0.010-0.036	0.058	
Organic nitrogen	0.21-0.47	6.10	0.40-0.49	3.0	-
Aluminum	0.005-1.56	0.44	0.11-3.1	1.4	0.075 (clay free)
Copper	0.001-0.004	0.009	0.002-0.003	0.42	0.005
Iron	0.09-0.98	3.0	0.10-0.81	0.94	0.3
Manganese	<-0.03	0.44	0.007-0.016	0.170	-
Nickel	<detection	0.044	<detection	0.575	0.025
Zinc	0.0005-0.028	0.50	0.001-0.004	0.150	0.03 (reduced to 0.016 in 1990)

ACKNOWLEDGEMENTS

This report is based on the work of dozens of staff who, through the years, have collected field samples, analysed them in the laboratory, and entered and retrieved the data. Since 1973 most of the responsibility and credit for maintaining the network and data collection in this region has been in the capable hands of Lawrence Baxter. Paul Burt has collected the monthly samples from the north shore of Lake Superior since 1980; supplementary sampling of the Pic and Little Pic Rivers is done by individuals from Marathon. The Kenora office has done the sampling in Kenora District in recent years.

The initial work in formatting the report, gathering information and developing methodology for the trend analysis was undertaken by Robert Steedman[1]. Mary Ellen MacCallum continued the writing of the report and provided the interpretation of the trend analysis data. The sections of the report pertaining to abatement measures are based, sometimes verbatim, on notes prepared by abatement staff in the two District Offices. Todd Kondrat generated the hundreds of figures that are the backbone of the report and was the primary editor. Matthew Janaszek also worked on the figures and Lawrence Baxter drew the maps. Rick Clara, Alice Chony and Colleen Cotter (OMOE Laboratory) helped clarify the information on the analysis of metals and microbiology. Arnold Laine and Shirley Remmen provided editorial assistance in preparing the final manuscript. Joyce Gammond typed the tables and much of the manuscript.

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1.0 INTRODUCTION

1.1 Objectives of the Provincial Water Quality Monitoring Network

Ontario's Provincial Water Quality Monitoring Network (PWQMN) was established in 1964 by the Ontario Water Resources Commission, to monitor the quality of Ontario's surface waters. The network is designed to address a number of key information requirements for management of water quality:

1) establish long-term baselines for various water quality parameters;

2) monitor compliance with Provincial Water Quality Objectives (PWQO's);

3) detect, characterize and define trends in the quality of surface waters;

4) provide information required for monitoring, compliance and control orders on industries and municipalities;

5) provide data for waste assimilation studies;

6) provide surveillance support for the International Joint Commission, by reporting nutrient and pollutant loadings into the Great Lakes and their tributaries; and

7) act as a mechanism to activate intensive surveys, enforcement proceedings and other policy actions related to water quality.

Information obtained through the PWQMN is used by the Ontario Ministry of the Environment (OMOE) to describe and predict changes in surface water quality, for planning and regulatory purposes. The data also are available to any person or agency concerned with the quality of Ontario's rivers and lakes. The booklet Water Management Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment, 1978 (Revised May, 1984) outlines OMOE's policies and objectives for water management in Ontario.

1.2 **Scope of this Report**

This report summarizes PWQMN information for 51 stations (see Appendix 1.1), and provides brief descriptions of pollution sources and pollution control measures associated with each station. Simple, graphical presentations of variability, trend and central tendency for selected water quality measures at each station are described. Contaminant levels are related to Provincial Water Quality Objectives, and where possible, to pollution control measures.

Several stations were not reported in this document. Sampling sites excluded were those on Lake Superior, special survey locations and discontinued stations (refer to Appendix 1.2). Further information on these stations is available from the Northwestern Regional OMOE office.

This report summarizes data (usually monthly) for up to 40 parameters that include conventional water quality parameters, metals and some bacteriological information. Although some data for pesticides and other organic compounds are available from some stations, they were not analyzed with the same frequency as other parameters and are not included in this synoptic overview.

Effluent toxicity and fish kills are two contentious issues outside the mandate of this report. Neither can be explained adequately by looking only at monthly data on conventional parameters. Determining the relationship of these phenomena with specific water quality parameters is beyong the scope of this report. However, where fish kills have occurred, and where effluents were toxic, this information is included as part of the description of general conditions.

1.3 Provincial Water Quality Monitoring Network in N.W. Region

In Northwestern Region, the Ontario Ministry of the Environment and its predecessor agency, the Ontario Water Resources Commission, have been operating the PWQMN since 1968. PWQMN stations in the Northwestern Region generally are located upstream and downstream from industrial or municipal sources of pollution (Fig. 1). Other stations monitor background water quality in relatively undisturbed watersheds on the north shore of Lake Superior. Data for some stations date from 1968, although many stations were established in the 1970's (Fig. 2).

Water quality information reported was obtained by multiple grab samples, taken 8-12 times per year at each station. Most analyses were performed at the Northwestern Region Laboratory in Thunder Bay. The specific chemical and bacteriological analyses performed for each water sample varied between locations. Parameters of concern were selected to monitor background water quality, municipal effluent, mining effluent, pulp mill effluent, etc. Laboratory procedures are described in Handbook of Methods for Environmental Samples (OMOE 1983, update in preparation). Physical data such as pH, dissolved oxygen and temperature were measured in the field.

PWQMN data are maintained in a centralized computer system, which can be accessed by Northwestern Region staff. After data are validated, they are transferred to the Sample Information System (SIS) operated by the OMOE at its Downsview Computing Centre. For this report, data was retrieved from SIS, reformatted and transferred to the Northwestern Region VAX minicomputer. The SAS statistical analysis system was used to produce summary graphs and to calculate summary statistics.

For more information about the Provincial Water Quality Monitoring Network, about specific water quality parameters, and about water quality monitoring in general, the reader is referred to recent volumes of Water Quality Data for Ontario Lakes and Streams, published annually by Water Resources Branch.

Hydrological information complementary to the PWQMN is provided by Environment Canada. Drainage areas and annual mean flows are summarized in Appendix 1.3. Monthly discharge records relevant to the PWQMN stations are available (Environment Canada 1989).

1.4 Previous OMOE summaries of water quality data in N.W. Region

The Ontario Ministry of the Environment has produced several documents that summarize different aspects of PWQMN data in northwestern Ontario: Klose 1988, OMOE (1972, 1978 and 1991). Other documents that contain valuable information about pollution sources, abatement measures and intensive water quality surveys are cited throughout this report. These citations are identified in the References section.

1.5 Characteristics of the PWQMN data set

1.5.1 Station numbering scheme

Each station is identified by name and by code. The code consists of 11 characters divided into four sub-fields, as follows:

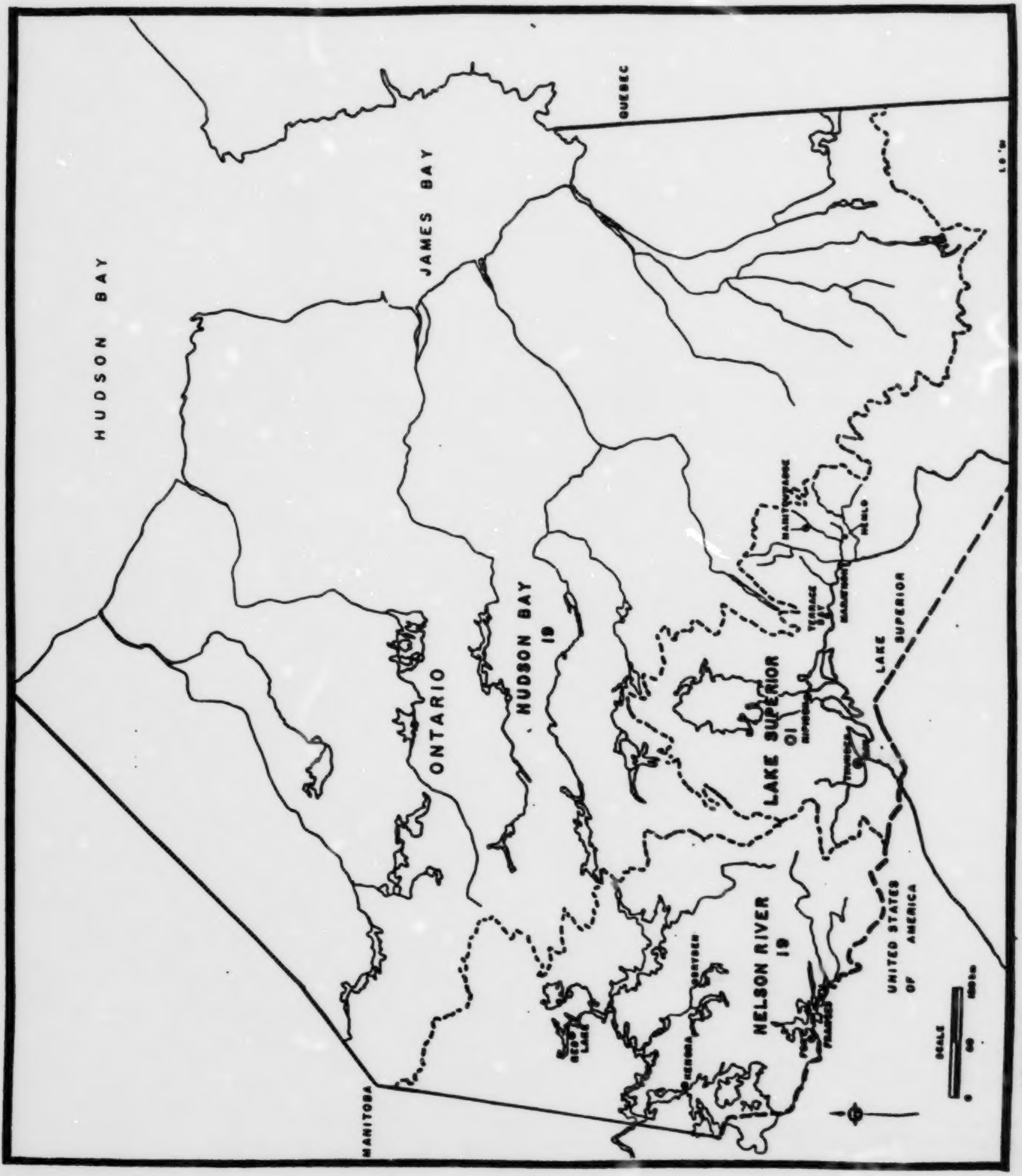

HUDSON BAY
JAMES BAY
QUEBEC
ONTARIO
HUDSON BAY
19
LAKE SUPERIOR
01
NELSON RIVER
19
LAKE SUPERIOR
MANITOUWADGE
HEMLO
MARATHON
TERRACE BAY
NIPIGON
THUNDER BAY
DRYDEN
KENORA
LAKE
FORT FRANCES
UNITED STATES OF AMERICA
MANITOBA
SCALE
0
50
100mi

FIGURE 1: MAJOR DRAINAGE BASINS AND TERMINAL STREAMS OF NORTHERN ONTARIO

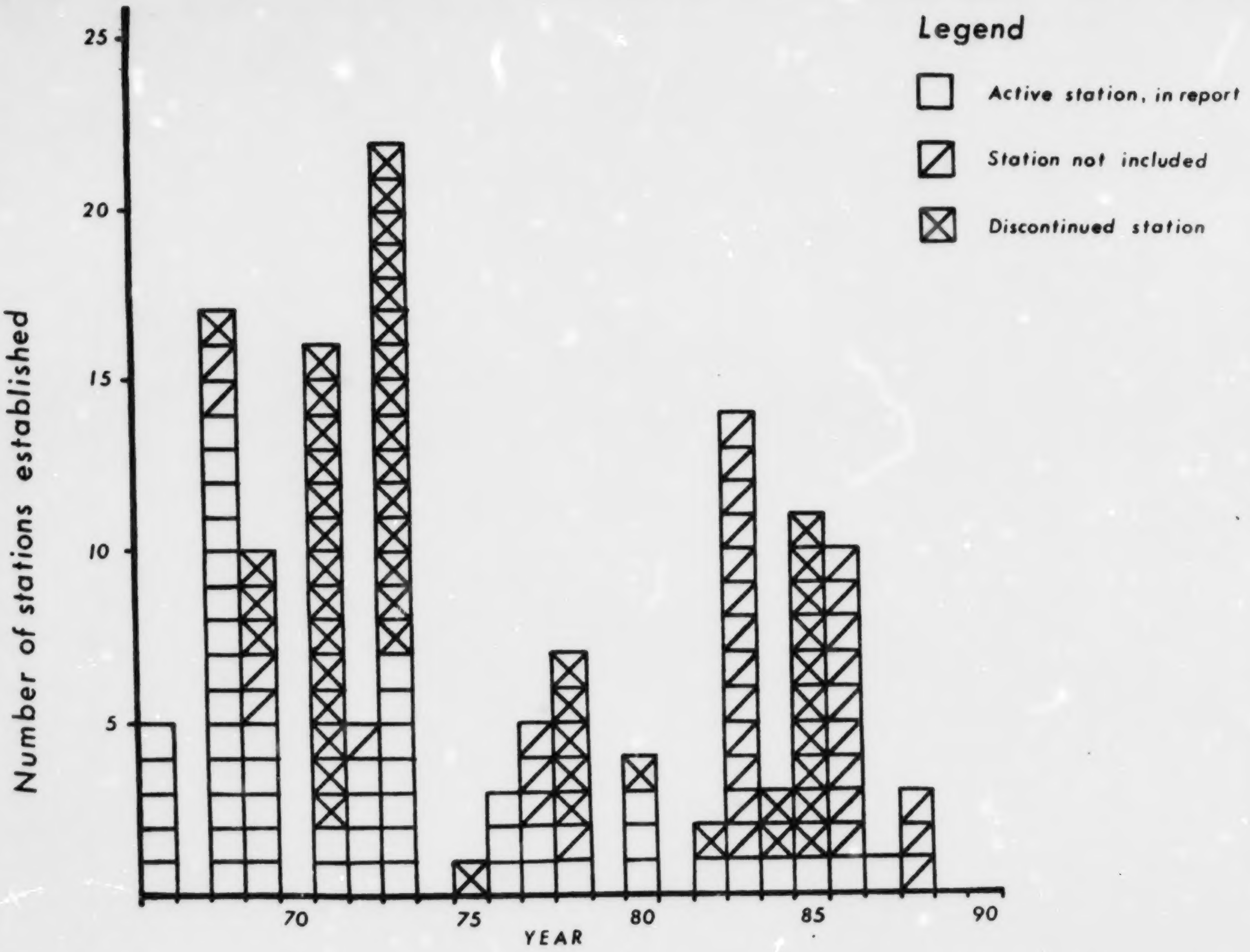


Figure 2. Date of establishment of PWQMN sites in NW region.

Basin - 2 characters
Terminal Stream - 4 characters
Station Number - 3 characters
Station Type - 2 characters

In Northwestern Region, there are two Basin designations: "01" for all waters tributary to Lake Superior, and "19" for all waters tributary to Hudson Bay. Terminal Streams are generally numbered from east to west along the Lake Superior or Hudson Bay shoreline. Station numbers generally reflect the sequence of station set-up, within a stream system. Station type "01" refers to a lake station; station type "02" refers to a stream or river station.

1.5.2 Changes in analytical capabilities and methods

Analytical methods are documented in the Handbook of Analytical Methods for Environmental Samples (HAMES)(OMOE 1983) and HAMES, Thunder Bay (OMOE 1990). The later also identifies changes in methods that occurred in the Thunder Bay laboratory, where most analyses have been done since about 1977, depending on the parameter. The sections of OMOE 1990 describing these changes and the dates when these moves occurred are given in Appendix 1.4.

The methodological change most likely to affect the comparability of the data was for colour (Remmen, S. 1991). It occurred in August 1985 (Appendix 1.4). Factors other than methodology that effect the data also were evaluated by lab staff for this report. They determined that the most important factor was the time between sampling and analysis. This lag was reduced, making the data more consistently reliable, as analyses were moved from Toronto to Thunder Bay.

Changes in detection limits (if they can be documented) are reported in Appendix 1.5. Caution is advised in interpreting data for metals within x10 to x20 of the low level reporting limit, especially prior to about 1980 (Boomer, D. 1991).

2.0 PRESENTATION OF RESULTS

2.1 Selection of parameters for illustration of time trends

Although data for up to 40 water quality parameters were retrieved for each station, only a subset of these was examined graphically in Section 3.0. Refer to Appendix 3.1 for median values of all 40 water quality parameters for each station.

In choosing water quality parameters to reflect key trends at each monitoring station, the main criterion was the nature of the effluent where a point source was being monitored. Below pulp mills, for example, coliform bacteria, biological oxygen demand (BOD_5), dissolved oxygen, conductivity, chloride, suspended solids (particulates) and nutrients are particularly relevant. Below base metal mines pH, conductivity, sulphate, chromium, copper, iron, nickel and zinc are of concern; gold mines may contribute arsenic and cyanide. Below a municipal sewage effluent bacteria, BOD_5, dissolved oxygen and nutrients are examined. If the station monitored background water quality in an undisturbed system, a core set of parameters including pH, conductivity, chloride, alkalinity, nutrients and metals such as zinc and copper would be used.

In reporting results, the term organic nitrogen is used to refer to total Kjeldahl nitrogen. The two are significantly different from each other only where ammonia levels are very high.

2.2 Data manipulation and analyses

In keeping with the principle of "letting the data speak for themselves", extensive data transformation and statistical analysis were not undertaken for this report. One important transformation was used, however, to facilitate calculation of summary statistics and graphical presentation of the data. Results of "undetectable" were transformed to "zero" prior to calculation of summary statistics and graphical presentation. This means that a "zero" measurement for certain substances does not mean that the substance was absent from the sample, only that levels were so low as to be undetectable with the existing analytical technique (refer to Appendix 1.5.2 for more information about detection limits of analyses discussed in this report). A number of other approaches may be used to analyze "censored" data of this type; they are summarized by Helsel (1990).

Time-series water quality data often have properties that limit the applicability of conventional statistical analyses (Bodo 1989). For this report, simple graphical presentations and median values are used to describe water quality. Water quality data for each station are presented using "box-whisker" diagrams (see Section 2.3), which graphically portray within-year variability and central tendency of water quality observations.

2.3 Graphical presentation of water quality trends

2.3.1 Use of the "five number summary" and "boxplots" (adapted from Bodo 1989)

Summary and graphical presentation generally should be a first step in understanding and analyzing environmental data sets, which are often large and have skewed, non-normal distributions. An important feature of preliminary or diagnostic data analysis is that the data should be allowed to "speak for themselves", without being subjected to strong distributional assumptions.

In many cases, useful inferences about central tendency and trend can be derived from this type of preliminary analysis. Formal confirmatory analysis with the objective of specifying precise confidence limits or statistical significance may not be warranted and has not been used in this report.

Order statistics and quantiles - Order statistics were used for data presentation as this type of data summary is well suited to exploratory analysis of central tendency and trend in larger data sets (Steedman and Bodo 1990, included as Appendix 2.1).

Central order statistics are robust: members of the data set (i.e. values) affect order statistics only through their relative ordering, not their magnitudes. For similar reasons, Order statistics also are a means of summarizing data sets containing censored observations (i.e. < detection) in most reasonably well-behaved cases.

Order statistics are derived from a rank-ordered data set. Thus order statistics are also quantiles or percentiles, i.e. the values associated with given cumulative fractions or percentages of the data distribution. Herein a quantile Q_t indicates that the value (number) given exceeds t% of the observations. For example, Q50 indicates the median, which is greater than 50% of the data (Steedman and Bodo 1990).

Tukey five number summary - Tukey (1977) presented the five number summary as a highly effective means of summarizing data. The five numbers are:

1. Sample maximum
2. Q75, 75th percentile or 3rd quartile
3. Q50, 50th percentile, 2nd quartile or median
4. Q25, 25th percentile or 1st quartile
5. Sample minimum

This list should be lengthened to include a sixth number, the sample size (Steedman and Bodo 1990). The sample size, n, from which these statistics are derived, is an important consideration which should always be reported in conjunction with the five order statistics listed above. Unlike the arithmetic mean and even the geometric mean in some cases, the median is a robust measure of location that is relatively insensitive to distribution shape and the presence of outliers.

The box-whisker diagram, or boxplot - Reckhow and Chapra (1983) and McLeod et al. (1983) introduced boxplots (App. 2.1, p. 8) to the water resources field, and this method has become widely used in technical journals and reports. Graphical presentation of the five number summary in the form of boxplots greatly enhances presentations of data. Location, scale, skew, extreme values and trend can be grasped at a glance.

BOXANNO.SAS - This program, listed with documentation in Appendix 2.1, uses BASE/SAS and SAS/GRAPH to produce box-whisker diagrams from a SAS data set. BOXANNO.SAS was used to produce the boxplots in Section 3.0.

2.3.2 Central tendency, variation, trend and cycles

The boxplots presented in Section 3.0 provide a means of visualizing the entire record of water quality measurement, for a given parameter at a given sample station. The information summarized by the boxplots allows the nature of both variation and trend in the data set to be easily extracted. The boxplots show both the annual mean and the annual median, as indicators of the location or central tendency of each year's group of measurements. As discussed in Section 2.3.1, the median is likely to be the more useful measure for the purposes of this report, provided that sample maximum and minimum also are known.

Which statistic is of greatest interest varies, depending on the different water quality parameters, and on different assessment purposes. For many parameters such as dissolved oxygen and pH, the annual minimum is most relevant to understanding biotic effects. For other parameters, including toxic metals, the annual maximum is likely to be most important; for bacteria, bioaccumulative substances or nutrients, a measure of central tendency may best reflect effects on biota or human use of water.

The rectangular portion or "box" on each boxplot symbol encloses the central 50% of each year's observations. If the distribution of a group of observations was approximately normal, this would represent ± about .67 standard deviations. For this report, evidence of trend was inferred if boxplots from successive years overlapped in less than 25% of their observations, i.e. if the bottom portion of the higher box did not overlap with the top portion of the lower box. Therefore, qualitative assessment of trends in the water quality data was determined relative to annual variation in the water quality measurements.

On figures where the scale of the vertical axis is such that Provincial Water Quality Objectives/Guidelines (PWQO/PWQG) values can be shown, a horizontal line was drawn to indicate the PWQO/PWQG value as of 1989. The PWQO for zinc was lowered from 0.03 mg/ℓ to 0.016 mg/ℓ in 1990 (OMOE). This is not reflected in the line since the change occurred after the period of the report.

The scale used on the vertical axis is dependent on the range of concentrations associated with a parameter, and varies from Figure to Figure. It is important for readers to note the different scales when making comparisons between stations.

The bacteriological data were the least amenable to the boxplot method of presentation because of the wide ranges in values, and because of interruptions in the record. In many cases, these data are not presented graphically because of the limited value of such presentations. Descriptions may be based on the original data.

In order to obtain an optimal scale for presenting the data, some figures are presented without including extremely high values. These figures are marked with an asterisk (*) and the excluded data are recorded in Appendix 2.2. From this table, it is apparent that two groups of excluded data were in error. In 1988, a series of pH values were recorded as zero; in 1970 one series of phosphorus values were extremely high. These two series have been excluded from the figures without using an asterisk (*).

2.4 Station Sequence

The stations are arranged by watershed within this report, and from upstream to downstream (where feasible). The report moves from east, starting with the White River to west within the Lake Superior drainage basin, and from south (Rainy River) to north (Red Lake) within the Winnipeg River drainage basin.

3.0 SURFACE WATER QUALITY NORTHWESTERN REGION

Because of the large amount of data collected by the PWQMN, written summaries in this section cover only the highlights. These descriptions include exceedances of PWQO/PWQG's and relate changes in water quality to abatement measures. For more comprehensive coverage, the reader is referred to the figures and tables of median values in the appendices. Complete records of the data are available on request.

Comprehensive background information on each station is provided. This includes station location, start date, purpose, and a parameter list. In addition, a brief **"Abatement History"** will document the nature of major point sources of pollution, and outline key steps that have been taken to reduce pollution.

3.1 Summary, North Shore of Lake Superior (Fig. 3)

The stations on the northshore of Lake Superior include 11 that monitor surface water quality associated with industrial sources and sewage treatment plants, and five that provide information on background water quality conditions of major tributaries near their points of discharge into Lake Superior.

Three of the industry-monitoring stations were established in 1984 in anticipation of the opening of the **Hemlo gold fields**. The results from Hayward Creek show a serious deterioration in water quality downstream from Lim Lake, which receives effluents from two mines. Concentrations of solutes such as chlorides and sulphates rose after the mines opened and continue to increase, while metals and cyanide periodically exceeded the provincial water quality objectives. In Cedar Creek, a comparison, made in the late 1980's, between conditions upstream and downstream of the mine water and sewage treatment discharges, indicated that nutrients, bacteria and other contaminants were entering the creek. Current data indicate that changes made in 1990 remedied the problem.

Six stations are associated with **Manitouwadge** and the nearby base metal mines. Fox Creek and the upper Black River have shown serious contamination with metals, and solutes, specifically sulphates, since the stations were established in the 1970's and 1980's. In Fox Creek the problem is attributed to seepage from an abandoned and an operational tailings area. Some improvement has occurred since the abandoned tailings area was revegetated in the late 1970's, but PWQO's still were exceeded in 1989. On the upper Black River the impact of the mine was evident at the station immediately below Mose Lake. Mose Lake is a severely degraded lake that receives mine effluent. Although some improvement has occurred since 1983, the impact on water quality continued to be seen 50 kilometres downstream, where levels of sulphate, ammonia and zinc levels were elevated. The station near the confluence of the Black River with the Pic River reported higher levels of most parameters than found at the upstream, background station. This reflects the overall accumulation of chemicals in the water from all sources, natural and industrial.

The station on Rudder Creek showed the effects of the wastewater treatment plant (WWTP) upstream. Phosphorus was higher here than at any other northshore station. Other conventional parameters and bacteria also were high, while most metals were similar to background levels. Little or no improvement can be seen since implementation of the new lagoon in 1986.

Blackbird Creek consists largely of effluent from a pulp and paper mill, and the water quality reflects this. The data reported here extend only up to 1988 when the location of the station was changed. The results showed extremely high biological oxygen demand (BOD_5), and high total and suspended solids, chlorides, conductivity, and bacteria. Dissolved oxygen levels sometimes were extremely low. Improvements were seen in several parameters. For example, problems associated with mercury contamination and fluctuating pH seem to have been largely resolved by a range of mill improvements. Data from the new station should indicate the effectiveness of recent abatement measures.

The remaining stations are near the mouths of major tributaries, and are used by the International Joint Commission to calculate loadings to Lake Superior of major contaminants. Except for the areas mentioned above, the drainage basins have relatively little development. Levels of the various parameters therefore are indicative of natural processes and from non-point sources such as atmospheric transport, limited rural run-off, and from forestry, roads, transmission lines and other dispersed activities. Levels range from the turbid Pic and Little Pic Rivers that are high in most parameters, to the clear waters of the Nipigon and White Rivers that show extremely low levels of most parameters. Metal levels often exceed PWQO's or guidelines in naturally turbid waters. Several parameters appear to fluctuate in multi-year cycles, showing a pattern that may relate to environmental factors such as precipitation or flow rates.

3.1.1 White River System

3.1.1.1 White River at Highway 17

Station code: 01-0057-001-02
Location: At Hwy. 17 (Fig. 3). Established 1973
Lat.: 48 43 24.33 **Long.:** 85 37 41.19
UTM: 16 0600900 5397400
Station type: surveillance, major tributary mouth, International Joint Commission
Test groups: TBWQM7 TBCM9
Receivers: L. Superior (south of Heron Bay)

Abatement History

This station is one of several that monitor nutrient loadings to the north shore of Lake Superior, under an agreement with the International Joint Commission. The Hemlo gold mines discharge their final effluents into tributaries of the White River downstream of this monitoring station.

Water quality, White River at Highway 17
(Figs. 34 - 36 and Table 4)

Nutrient levels are low in the White River; median values for total phosphorus and organic nitrogen are .009 mg/ℓ and .03 mg/ℓ respectively. Metals are also low and rarely exceeded provincial guidelines or objectives. Water Quality in the White River is compared to other rivers that flow into the north shore Lake Superior in Section 3.1.7.

3.1.1.2 **Hayward Creek**

Station code: 01-0057-002-02
Location: Downstream Molson and Lim Lakes at forest access road (Fig. 3).
Lat.: 48 39 17.11 **Long.:** 85 53 33.7
UTM: 16 581550 5389450
Station type: diffuse sources: extractive industrial land and point source: mining.
Test groups: TBCR4 - BOD5 + SBUT +CCNAUR
Receivers: White River, L. Superior

Abatement History (from Laine 1991)

Hemlo Gold Fields

With the discovery of substantial gold deposits in 1980, the Hemlo area, adjacent to Hwy. 17, 35 km east of Marathon, became the focus of extensive exploration activity. Mine and mill developments by Williams Operating Corp. (formerly Lac Minerals Inc.), the Golden Giant mine (Hemlo Gold, previously Noranda Inc., Hemlo Project) and the David Bell mine (Teck-Corona Operation Corp.) soon followed.

The Hemlo area forms part of the Black River and White River watersheds, both of which flow into Lake Superior. Waters that receive effluent from mining and milling operations at Hemlo include Cedar Creek (see Section 3.1.2.4) (tributary to the Black-Pic River system) and Hayward and Frank Creeks (tributaries to the

White River). The following discussion relates mainly to effects of final tailings effluent, discharged to Hayward Creek.

In the Hemlo area, sample stations for the PWQMN have been established on Cedar Creek above and below the mines, and on Hayward Creek below Lim Lake. Lim Lake receives final effluent from the David Bell and Golden Giant mines. At present, there is no station below Frank Lake, which receives final effluent from the Williams mine, due to the lack of road access. The White River below Hemlo is not accessible by road.

The David Bell, Golden Giant and Williams mines used staged development to reach present production rates of 1250, 3000 and 6000 tonnes/day (t/d), respectively. All three mines had planned project lifespans of approximately 20 years, based on originally defined ore reserves.

All three mines use a cyanide-based milling/gold recovery process. Following gold recovery, the tailings are discharged to their respective tailings facility to allow settling of suspended solids, and the volatilization and destruction of cyanide by photodecomposition. Some of the decant from the tailings area is used in the mill water-recycling circuit, the remainder is sent to the effluent treatment plant before final discharge.

The final effluent treatment process involves two treatment steps to remove cyanide and heavy metals. The first step destroys cyanide and metallo-cyanide complexes, and begins removal of some of the heavy metals. The second step uses ferric iron coprecipitation to remove more persistent heavy metals such as antimony and molybdenum. The effluent treatment process was changed in 1985, with further modifications since, to provide improved removal of metals. The effluent also contains minewater with high levels of ammonia. Following treatment, the effluents are discharged to Lim Lake (David Bell and Golden Giant) and Frank Lake (Williams). Effluents that exceed provincial toxicity standards are re-directed to the tailings area.

Water quality, Hayward Creek (Figs. 4 - 7 and Table 1)

Discharge from Lim Lake makes up most of the flow of Hayward Creek. Conductivity, chlorides and sulphates are elevated and are increasing. Cyanide, ammonia, mercury, nickel and copper were high and have exceeded PWQO's. Variability in phosphorus and pH increased over time, with low pH of 5.9 in 1989. These observations, combined with data from other sources suggest that Lim Lake does not have the ability to assimilate the contaminants discharged in the effluent.

3.1.2 Pic River System

3.1.2.1 Rudder Creek

Station code: 01-0060-007-02
Location: 5 km west of Hwy. 614 (Fig. 3). Established 1977
Lat.: 49 07 00.61 **Long.:** 85 54 25.67
UTM: 16 0579750 5440800
Station type: point source, sewage treatment plant
Test groups: TBWQM5 TBCM4 - SI03UR +ASUT
Receivers: Fourbay Ck., Nama Ck., Pic R., L. Superior

Abatement History

Rudder Creek is a small headwater stream that receives municipal sewage effluent from the Town of Manitouwadge. Until 1986, sewage from the collector system was pumped to a communal septic tank, and flowed to Rudder Creek via a swampy area known as Rudder Lake. In November 1986, a new aerated lagoon was put into operation that also discharges into Rudder Creek via Rudder Lake.

Water quality, Rudder Creek (Figs. 8 - 10 and Table 1)

Conventional Parameters

In comparison to background levels in the upper Black River, alkalinity, BOD_5, chlorides, conductivity, nutrients, suspended solids and sulphates in Rudder Creek were all elevated. The median value of total phosphorus (0.93 mg/ℓ) was higher here than at any other station on the north shore.

Total and fecal coliforms often exceeded recommended objectives (<1000 counts/100 ml and <100 counts/100 ml respectively). Measurement of these parameters was discontinued in 1984.

Metals

There is little evidence of improvement in water quality since the lagoon has been in operation. Alkalinity, chlorides, conductivity and total phosphorus reached their highest annual median values in 1989.

Metal levels were similar to background values, with zinc, iron, chromium and aluminum concentrations that occasionally exceed PWQO's or guidelines.

3.1.2.2 Fox Creek

Station code: 01-0060-008-02
Location: At inflow to Manitouwadge Lake (Fig. 3) Established 1980
Lat.: 49 08 40.19 **Long.:** 85 47 38.71
UTM: 16 0587950 5444000
Station type: diffuse source - extractive industrial land downstream from mine seepage
Test groups: TBWQM5, TBCM4 - SI03UR +ASUT
Receivers: Manitouwadge L., Mose L., Black R., Pic R., L. Superior

Station code: 01-0060-005-02
Location: At Hwy. 614, Manitouwadge Lake (Fig. 3). Established 1976
Lat.: 49 07 58.93 **Long.:** 85 47 42.18
UTM: 16 0587900 5442725

Station type: diffuse source - extractive industrial land downstream from mine seepage.
Test groups: TBWQM5, TBCM4 - SI03UR +ASUT
Receivers: Manitouwadge L., Mose L., Black R., Pic R., L. Superior

Abatement History

Lac Minerals Inc.; Willroy Mine

Between 1957 and 1977, Willroy Mines Ltd. operated a copper-lead-zinc mining and concentrator complex in the Township of Gemmell at Manitouwadge, Ontario. Tailings from the operation were deposited in a long, narrow valley west of the mill, which was developed as three cells by the construction of dams across the valley. In addition to the tailings containment dams, a fourth dam was constructed to form a settling pond for effluent treatment prior to its discharge. Treated effluent was discharged from the settling pond into a small creek ("Agam Creek") which drains into Camp Lake and ultimately into Manitouwadge Lake.

During the operation of the Willroy mine, tailings began to seep into a tributary of Fox Creek. As a remedial measure, the company constructed a containment area where the seepage was collected and pumped back into the tailings area. This system reduced the amount of seepage entering into Fox Creek but did not eliminate it. Seepage from the Geco Mine to the east also enters Fox Creek (Section 3.1.2.3).

In 1977 the mine closed and an intensive reclamation program was initiated. All exposed tailings have been covered and vegetated. In 1984 the company reported flow from the tailings area to be approximately 0.01 m^3/s during the summer months, with peak flows of up to 0.11 m^3/s during the spring and fall.

Water quality, Fox Creek: (Figs. 11 - 14 and Table 2)

Contamination was most severe at the station located at the inflow to Manitouwadge Lake. Both Fox Creek stations have elevated levels of sulphates, zinc, copper, lead and iron when compared with background levels in the upper Black River (see Table 2). Although there is some indication that levels of contamination at both stations have declined during the early 1980's, they continued to exceed PWQO's in most samples. At the inflow to Lake Manitouwadge, pH values were low (median, 7.1) but have risen since 1986. Ammonia levels were comparable to background levels, and lower than a mean value of 0.99 mg/ℓ measured by German (1972). Sulphate levels decreased to about 1/3 of 1970 levels, but were still well above background levels (median of 2 mg/ℓ for upper Black River). There was little evidence of any bacterial contamination.

3.1.2.3 **Upper Black River**

Station code: 01-0060-006-02
Location: Upstream of Mose Lake (Fig. 3). Established 1977.
Lat.: 49 08 30.01 **Long.:** 85 44 23.99
UTM: 16 0591900 5443750
Station type: surveillance, background.
Test groups: TBWQM5, TBCM4 -SI03UR +ASUT.
Receivers: Mose L., Black R., Pic R., L. Superior

Station code: 01-0060-004-02
Location: 1 mile below outlet of Mose Lake (Fig. 3). Established 1976.
Lat.: 49 08 08.40 **Long.:** 85 44 46.75
UTM: 16 0591450 5443075
Station type: diffuse source, extractive industrial land and point source, mining.
Test groups: TBWQM5, TBCM4 -SI03UR +ASUT.
Receivers: Pic R., L. Superior.

Station code: 01-0060-003-02
Location: at Hwy. 614 south of Agonzon (Fig. 3). Established 1976.
Lat.: 48 52 43.90 **Long.:** 85 52 48.98
UTM: 16 0582100 5414375

Station type: diffuse source, extractive industrial land.
Test groups: TBWQM5, TBCM4 -SI03UR +ASUT.
Receivers: Pic R., L. Superior.

Abatement History

Noranda Minerals Inc.; Geco Mine

Three stations on the upper Black River monitor the effects of past and present mining activities near Manitouwadge. Station -0060-006-, upstream of Mose Lake, serves as a control. Station -0060-004- monitors discharge from Mose Lake, which has been severely degraded by mining effluent, and is permanently stratified with a chemical gradient (a chemocline). Station -0060-003-, 50 kilometers downstream, monitors the recovery of the Black River downstream of the Manitouwadge area.

Noranda-Geco operates a copper, zinc, lead and silver mine in the town of Manitouwadge, Ontario. The mine commenced operations in 1957 at a 3,300 tons/day milling rate and added a lead recovery unit in 1961. Milling capacity was increased to 5,000 tons/day in 1970.

Tailings from the mill are deposited in a main tailings pond located on site. Prior to 1976, untreated effluent was discharged from the main tailings pond directly into Mose Lake. In 1977, the company put into operation a waste water treatment plant which treated a portion of the tailings water prior to its discharge into Mose Lake. However, during spring runoff and fall rains the tailings area was still permitted to overflow into Mose Lake. Recent improvements in effluent and seepage collection have substantially reduced metal loadings to Mose Lake, however, final effluent still exceeds provincial toxicity standards.

The use of anhydrous ammonia in the mill to control pH resulted in very high levels of ammonia in the effluent discharged to Mose Lake. In 1987, a trial ammonia reduction program was implemented that utilized quick lime in the zinc and lead circuits.

Water quality, Upper Black River (Figs. 15 - 23 and Table 2)

Conventional Parameters

Sulphates, conductivity and ammonia were high at the station one mile downstream from the outlet of Mose Lake; un-ionized ammonia exceeded the PWQO on several occasions. Declines in all three parameters were observed in 1988, but levels were high again in 1989. Chlorides and pH were at background levels.

Fecal coliform counts only rarely exceeded 100 counts/100 ml, the level considered too high for swimming.

Metals

One of the consequences of the accumulation of sulphates, etc. in Mose Lake, and of the related chemocline has been a reduction in the lakes ability to assimilate contaminants such as metals. Zinc, copper, and, to a lesser extent, iron were elevated at the outflow from Mose Lake (median values of .010 mg/ℓ, .007 mg/ℓ and 0.44 mg/ℓ respectively) as compared to background levels. All three parameters exceeded Provincial Water Quality Objectives at the outlet of Mose Lake, although levels have declined since 1983. Since 1987, nickel and chromium values have been undetectable; a similar decline occurred in background concentrations.

Elevated parameters show some reduction 50 kilometers downstream at the station south of Agonzon. However, sulphates, ammonia and zinc remain at least double the levels found upstream of the point source. Although no time trends are evident in this data set, median levels (but not maxima) are substantially reduced from mean levels reported by German (1972).

3.1.2.4 **Cedar Creek**

Station code: 01-0060-010-02
Location: at Hwy. 17 (Fig. 3). Established 1983
Lat.: 48 41 47.30 **Long.:** 85 52 51.34

UTM: 16 0582350 5394100
Station type: background, upstream of mines.
Test groups: TBWQM5, TBCM6 -SI03UR +CRUT, CCNFUR, CCNAUR
Receivers: Black R., Pic R., L. Superior.

Station code: 01-0060-012-02 (downstream of mines)
Location: at hydrometric station, downstream of Hwy. 17. Established 1984.
Lat.: 48 42 20.68 **Long.:** 85 54 35.80
UTM 16 0587950.0 5444000.0
Station type: diffuse source, extractive industrial land.
Test groups: TBWQM5, TBCM6 -SI03UR +CRUT, CCNFUR, CCAUR
Receivers: Black R., Pic R., L. Superior.

Abatement History

Hemlo Gold Fields

Cedar Creek is used as a source of process water, and as a waste water receiver for Hemlo Gold, Williams Operating Corp., and Teck-Corona Corp., the three companies active in the Hemlo gold field. The Cedar Creek stations, -0060-010-and -0060-012-, are located upstream and downstream respectively of the mine areas, and monitor mine water and sewage treatment discharges. All mines commenced operations in 1985. A detailed description of the operations was provided in Section 3.1.1. In 1990, steps were taken to eliminate discharges to Cedar Creek; measures to ensure that adequate flow is maintained also are being implemented. The figures pre-date these changes.

Water quality, Cedar Creek (Figs. 24 - 30 and Table 1)

Phosphorus, nitrogen, and bacterial (fecal coliform) levels in Cedar Creek rose after 1984, as a result of inputs from domestic sewage and explosives residues; maximum phosphorus levels exceeded PWQO's at the downstream station. Increases in alkalinity, conductivity, pH and sulphates also occurred. Preliminary evaluation of 1990 data suggests that water quality has improved since discharges to Cedar Creek were discontinued.

3.1.2.5 **Black River at Highway 17**

Station code: 01-0060-002-02
Location: at Hwy. 17 (Fig. 3). Established 1973.
Lat.: 48 41 16.70 **Long.:** 86 12 46.73
UTM: 16 0557925.0 5392850.0
Station type: surveillance, major tributary mouth, International Joint Commission.
Test groups: TBWQM5, TBCM4 -S103UR -ASUT.
Receivers: Pic R., L. Superior.

Abatement History

This station is near the confluence of the Black River with the Pic River, and was established to monitor whole-watershed effects, including inputs from the Manitouwadge and Hemlo mining operations. Sections 3.1.2.1 -3.1.2.4 describe industrial activities on this river. This station also is one of several that monitor nutrient loadings to the north shore of Lake Superior, under an agreement with the International Joint Commission.

Water quality, Black River at Hwy. 17 (Figs. 37 - 39 and Table 4)

Median copper and zinc levels (.004 mg/ℓ and .002 mg/ℓ respectively) at this station were low and have declined in recent years. A comparison of additional parameters for north shore rivers is included in Section 3.1.7.

3.1.2.6 **Pic River at Highway 17**

Station code: 01-0060-001-02
Location: at Hwy. 17. Established 1973 (Fig. 3)
Lat.: 48 42 25.57 **Long.:** 86 17 01.32
UTM: 16 0552700.0 5394925.0
Station type: surveillance, major river mouth, International Joint Commission

Test groups: TBWQM6, TBCM8, PCBT (not included in report)
Receivers: Lake Superior (south of Heron Bay)

Abatement History

This station is one of several that monitor nutrient loadings to the north shore of Lake Superior, under an agreement with the International Joint Commission. Sections 3.1.2.1 - 3.1.2.5 describe industrial activities in this drainage basin.

Water quality, Pic River at Hwy. 17 (Fig. 40 - 43 and Table 4)

The Pic River was the most turbid river of those monitored on the north shore of Lake Superior, with a median suspended solids (RSP) level of 60 mg/ℓ. Nutrient levels and most metals were higher than other north shore rivers. Median copper and zinc concentrations in the Pic River were below Provincial Water Quality Objectives, but individual observations often exceeded them. Iron levels usually exceeded PWQO's, median value of .95 mg/ℓ. Aluminum levels also were high (median value of 1.56 mg/ℓ).

3.1.3 Little Pic River at Highway 17

Station code: 01-0067-001-02
Location: at Hwy. 17. (Fig. 3). Established 1973
Lat.: 48 48 04.22 **Long.:** 86 37 53.94
UTM: 16 527050 5405200
Station type: surveillance, major tributary mouth, International Joint Commission
Test groups: TBWQM7, TBCM9, PCBT (not included in the report)
Receivers: Lake Superior

Abatement History

There is no point source near this station. It is one of several that monitor nutrient loadings to the north shore of Lake Superior under an agreement with the International Joint Commission.

Water Quality Little Pic River at Hwy. 17
(Figs. 44 - 46 and Table 4)

Like the Pic River, the Little Pic was turbid with high levels of suspended solids, nutrients and metals. However, values were not as extreme. For a comparison with the Pic and other north shore rivers see Section 3.1.7.

3.1.4 Blackbird Creek

Station code: 01-0074-001-02
Location: at Hwy. 17. (Fig. 3). Established 1973, discontinued, 1987. Replaced by 01-0074-002-02. (data from -0074-002- have not been included in this report)
Lat.: 48 49 48.27 **Long.:** 87 04 28.55
UTM: 16 0494525.0 5408350.0
Station type: industrial point source (pulp and paper)
Test groups: TBWQM8, TBCM6, -ASUT, +CRUT
Receivers: Lake Superior (Moberly Bay)

Abatement History

Kimberly-Clark of Canada

A bleached kraft pulp mill, owned by Kimberly-Clark Canada Inc. has been located in Terrace Bay since 1949. From 1973 to 1986 between 96,000 and 450,000 cubic metres of raw water per day were used to produce between 262 and 1182 tonnes of bleached kraft pulp per day (monthly averages). The original mill design capacity of 320 t/d was expanded to 815 t/d over the period of 1975 to 1978. The expanded mill complex produced high grade bleached kraft pulp using two 6-stage bleacheries.

The mill effluents are partially segregated. The bleachery acid sewer receives the discharges from the once-through chlorine and chlorine dioxide stages in the old mill bleachery, and from the overflow from the first stage chlorine dioxide/chlorine stage in the countercurrent bleachery in the new mill. The alkaline sewer receives all the other discharges from both mills.

Prior to completion of the mill expansion in 1978, the old mill was operating as high as 25% above its design capacity of 320 t/d with an annual average loading of suspended solids ranging between 6.4 and 8.5 t/d, and with BOD_5 ranging between 28.9 and 38.8 t/d. These levels are roughly twice the levels recommended for kraft mills (<10 kg suspended solids/t) by the Expert Committee on Kraft Mill Toxicity (Bonsor et al. 1988). The annual average water consumption ranged between 185,000 and 210,000 m^3/day.

During the mill expansion from 1975 to 1978, several pollution abatement measures were incorporated to reduce the volume of effluent and the loading rates from the mill complex. These measures included conversion of the woodroom to dry debarking, installation of two primary clarifiers and ancillary effluent treatment plant equipment, installation of a spills pond, steam stripping of condensates, expansion of the turpentine and soap collection systems, countercurrent washing in the new bleachery, and installation and upgrading of the brown stock washers in both mills to four stage washers. The chlor-alkali plant that was a source of mercury contamination was replaced by a chlorine dioxide generator. The use of mercury-based fungicides also was discontinued.

While the production increased during 1978 to 1982 to over 1000 t/d, the suspended solids losses decreased from between 6.4 and 8.5 t/d (between 1973 and 1977), down to as low as 5.4 t/d in 1981. Water conservation measures implemented during this period reduced the total water consumption by 40%, while the mill capacity more than tripled during the same period, from 320 t/d to 1135 t/d.

Following a serious mill fire on October 30, 1981, an extensive four-month reconstruction was undertaken. During the reconstruction, much of the pollution abatement equipment was serviced and its operation improved. This included the installation of a turpentine decanter, a condensate stripper and non-condensate gas (NCG) collection and destruction system.

In response to a 1982 Control Order, a spills collection system was established in 1983, and improvements were made to the number 2 brown stock system. In 1984, number 1 brown stock washer was altered to improve soap recovery and foam control; a polymer feed control system was added to the alkaline clarifier; an additional clarifier was installed at the causticizing plant; and number 1 mill was dedicated to hardwood. These measures resulted in significant reductions in effluent volume, and its load of BOD_5 and suspended solids. In 1985/86 soap recovery was improved and bleachery operations were modified to use higher oxygen and chlorine dioxide substitution. In 1987, steps were taken to reduce effluent toxicity with an improved black liquor spill collection system and effluent neutralization. In 1988, construction of an aerated stabilization basin commenced, to provide secondary treatment of final effluent. To neutralize and stabilize the pH of effluent from alkaline and acid sewers, a mixing chamber for these discharges was incorporated into the basin. This basin became operational in September, 1989. Final effluent was usually acutely toxic previous to 1989. Toxicity reduction was greatly enhanced after implementation of secondary treatment.

Water Quality Blackbird Creek (Figs. 31 - 33 and Table 3)

Blackbird Creek is a small watercourse and the effluent from Kimberly-Clark can account for much of its flow.

Conventional Parameters

Some improvement in BOD_5 was seen over time although levels remained extremely high (median = 180 mg/ℓ). Levels of total and suspended solids declined briefly after the expansion in 1978, were high in 1981, and fluctuated around a median of 50 mg/ℓ after that time. Over the period of record, beginning in 1973, there was a general upward trend in conductivity and chloride values until 1980/81. After the upgrading in 1981 conductivity and chloride levels decreased markedly until 1984, but had levelled off at approximately 1500 umhos/cm and 300 mg/ℓ respectively (as of 1987) despite further abatement measures.

Phosphorus increased after expansion in 1978, although it has shown fewer extremes since the 1981 upgrading. Organic nitrogen rose through the 1980's and was variable.

Other than BOD_5 (see above), the water quality problems of greatest concern were pH fluctuations and low dissolved oxygen levels. Values for pH were high during the 1970's, probably reflecting discharges from alkaline sewers. In 1980, low pH's also were encountered, probably reflecting acid sewer discharges. The annual range that was observed over the 1980's violated PWQO's at both extremes: the PWQO is to maintain a pH of 6.5-8.5, the range more typical of Blackbird Creek was from 3.5 (or lower) to 10. Dissolved oxygen levels were also severely depleted. Between 1984 and 1987, extreme lows of 1 mg/ℓ and median values of less than 3 mg/ℓ were reported annually.

Total coliform (TCMF) levels were extremely high during the early 1980's (TCMF > 3 x 10^8). *Pseudomonas* bacteria, which generally are associated with sewage, were also found. After 1986, levels of coliform bacteria dropped slightly, however, levels remained elevated.

Metals

Mercury levels declined after the sources were eliminated; chromium contamination persisted.

The figures do not include data after 1987, when abatement measures were taken. However, a review of maximum and mean values from the new station for 1988 and 1989 did not show any obvious improvements in water quality. The impact of secondary treatment on water quality in Blackbird Creek should be apparent in the 1990 data.

3.1.5 Nipigon River at Highway 17

Station code: 01-0090-002-02
Location: at Hwy. 17. (Fig. 3). **Established** 1973
Lat.: 49 01 11.56 **Long.:** 88 15 02.77
UTM: 16 0408550.0 5430200.0
Station type: surveillance, major tributary mouth, International Joint Commission
Test groups: TBWQM6, TBCM8
Receivers: Lake Superior (Nipigon Bay)

Abatement History

This station is one of several that monitor nutrient loadings to the north shore of Lake Superior, under an agreement with the International Joint Commission.

Water quality, Nipigon River at Highway 17
(Figs. 47 - 49 and Table 4)

The Nipigon River has more than twice the flow of the Kaministiquia River, the next largest river entering the Canadian waters of Lake Superior, with a mean total annual discharge of more than 110×10^6 cubic meters (Appendix 1.3). Its flow is regulated by hydro electric dams. It had fewer solids and lower levels of conductivity, phosphorus and metals than the other major tributaries. (See Section 3.1.7).

3.1.6 Black Sturgeon River at Highway 17

Station code: 01-0092-001-02
Location: at Hwy. 17. (Fig. 3). **Established** 1973
Lat.: 48 54 15.06 **Long.:** 88 22 39.06
UTM: 16 399050 5417500
Station type: surveillance, major tributary mouth, International Joint Commission
Test groups: TBWQM7, TBCM9
Receivers: Lake Superior (Black Bay)

Abatement History

This station is one of several that monitor nutrient loadings to the north shore of Lake Superior, under an agreement with the International Joint Commission.

Water quality, Black Sturgeon River at Highway 17
(Figs. 50 - 52 and Table 4)

Water quality in the Black Sturgeon River is compared to that of other major tributaries of Lake Superior in Section 3.1.7. It had slightly elevated levels of copper (median value of .004 mg/ℓ) and exceeded PWQO's at least once most years.

3.1.7 Major tributaries of Lake Superior (Table 4)

White River (-0054-001-)
Black River (-0060-002-)
Pic River (-0060-001-)
Little Pic River (-0067-001-)
Nipigon River (-0090-002-)
Black Sturgeon River (-0092-001-)

Median values for ten parameters are listed in Table 4. Other parameters, including those that have an incomplete data set are shown in Figs 34-52. Appendix 3.1 lists median values for all parameters in the SAS data base.

In general, the Pic River, and to a lesser extent, the Little Pic River, was characterized by the high loads of suspended solids, total phosphorus, and several metals, while the Nipigon and White Rivers were nutrient poor and relatively low in metals.

Conventional Parameters

Values for many conventional parameters were relatively low, as is typical of waters on the Precambrian Shield. Ranges of medians values (in mg/ℓ, except conductivity) for the stations were as follows:

alkalinity: 59 (Black Sturgeon R) to 98 (Pic R)
conductivity: 145 (Nipigon R) to 216 (Black Sturgeon R)
total phosphates: 0.008 (Nipigon R) to 0.045 (Pic R)
organic nitrogen: 0.02 (Nipigon R) to 0.46 (Little Pic)

Most conventional parameters, including alkalinity, conductivity and total phosphorus vary from month to month, with no obvious long term trends. There is some evidence that some of these, notably conductivity, may be cyclical. At several stations, pH decreased between 1973 and 1976, increased back to 1973 levels by 1981, then fluctuated around this value. Several parameters including particulate matter (RSP), chlorides and total phosphorus, typically were low or non-detectable, with occasional high values.

Levels of bacteria in these rivers were low. Since 1984, analyses have been done only for fecal coliforms.

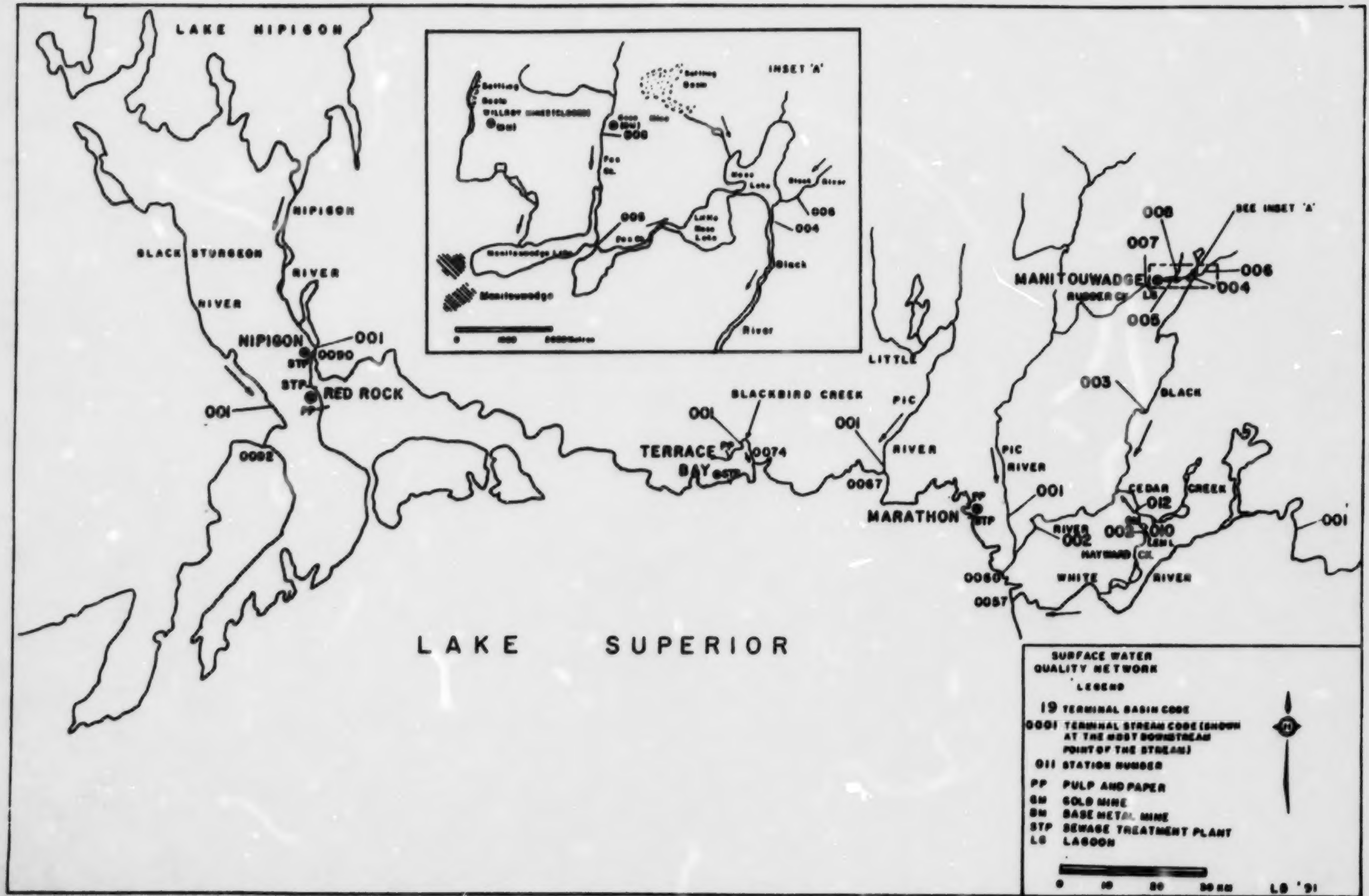
Metals

Metals were relatively high, a reflection of underlying geology and atmospheric deposition. Median zinc levels (mg/ℓ) ranged from 0.006 (Pic River) to .015; copper levels (mg/ℓ) were near or above PWQO's with median values from 0.001 (White River) to 0.004 (Pic and Black Sturgeon Rivers); and iron (mg/ℓ) was high (0.14 on White River to 1.20 on the Little Pic River). Aluminum was high on the Little Pic (0.98 mg/ℓ and Pic Rivers 1.56 mg/ℓ).

Trends for metals are specific to the metal. Zinc was usually detectable and occasionally in exceedance of PWQO's. Levels have declined on the Black, White and Nipigon Rivers since 1983. Copper usually was detectable and often in exceedance of PWQO's. Copper may have been declining on some rivers (the Black, Black Sturgeon, and Nipigon Rivers) since the mid 1980's. Iron almost always was detectable, often high and frequently in exceedance of PWQO's. Aluminum values were high on the Pic and Little Pic and often in exceedance; this parameter has been reported only since the mid

1980's. Manganese values were highly variable.

Other metals usually were not detected in ambient monitoring surveys. Cadmium often was not detectable. Because PWQO's are near the limits of detection, information on exceedances is not reliable. Chromium levels have declined since the early 1980's and were detected in less than half the samples. They usually were low but sometimes exceeded the PWQO on the Pic and Little Pic Rivers. Arsenic usually was not detectable; if detected, the values usually were very low, and were always below the PWQO. Mercury has been detected on all five rivers more frequently in the late 1980's. The high levels detected in the late 1970's may be the result of sampling or analytical problems (see Sec. 3.4).


LAKE NIPIGON
NIPIGON
RIVER
BLACK STURGEON
RIVER
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001
0090
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STP
RED ROCK
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0092
BLACKBIRD CREEK
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TERRACE
BAY
PP
0074
STP
LITTLE
PIC
001
RIVER
0067
MARATHON
PP
STP
PIC
RIVER
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MANITOUWADGE
RUBBER CK
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BLACK
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CREEK
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RIVER
HAYWARD CK.
WHITE
RIVER
0060
0057
001
LAKE SUPERIOR
INSET 'A'
Settling Basin
Settling Basin
008
Fox Cr.
Mose Lake
Little Mose Lake
Manitouwadge Lake
Manitouwadge
005
006
004
Black
River
SURFACE WATER
QUALITY NETWORK
LEGEND
19 TERMINAL BASIN CODE
0001 TERMINAL STREAM CODE (SHOWN AT THE MOST DOWNSTREAM POINT OF THE STREAM)
011 STATION NUMBER
PP PULP AND PAPER
GM GOLD MINE
BM BASE METAL MINE
STP SEWAGE TREATMENT PLANT
LS LAGOON
0
10
20
30 KM
LS '91

FIGURE 3: WATER QUALITY MONITORING LOCATIONS AND POINT SOURCES ON THE NORTH SHORE OF LAKE SUPERIOR

Table 1: Selected water quality data[1] for Hemlo area and Rudder Creek

Station	Alkalinity mg/ℓ	BOD mg/ℓ	Chloride mg/ℓ	Conductivity μs	pH	Solids mg/ℓ	SO_4 mg/ℓ	Total Phosphorus mg/ℓ	Nitrogen mg/ℓ	Copper mg/ℓ	Nickel mg/ℓ	Other Hg/μg/ℓ
Hayward Cr. (-0057-002-)	21		46.0 1.03*	1001	7.0 5.9**	RST:780 1860* RSP:1	379	0.010	NHT: 3.90 NHT:13.0* NTK: 6.10	0.009 0.026*	0.044 0.091*	Hg 0.03 Hg 0.36* Cyanide 0.02
Cedar Cr. U/S (-0060-810-)	56 70*	0.7 1.4*	3.7 37*	134 1730*	7.4 8.0* 6.9**	RST:110 RSP:1	3.9 30.3*	0.012 0.02*	NHT:0.02 NHT:0.08* NTK:0.46 NTK:0.66*	0.001 0.003*	< 0.005*	Zn < Zn 0.005* Hg < Hg 0.006* As < AS 0.012*
Cedar Cr. D/S (-0060-012-)	59 80*	1.0	5.6	163 343*	7.6 9.5* 7.2*	RST:120 RSP:1.5	7.5 50.2*	0.018 0.077*	NHT:0.12 1.0* NTK:0.73 1.8*	0.001	<	Zn 0.001 Hg < As <
Black River at Hwy 17 (-0060-002-)	78	1.0	1.0	182	7.9	RST:160 RSP:15	7.0	0.016	NHT:0.04 NTK:0.48	0.003	<	Zn 0.015
Rudder Cr. (-0060-007-)	169 361*	1.6 15*	26.0 95*	445 972*	7.6 9.3*	RST:290 RST:590* RSP:3 RSP:60*	20.0 51.6*	0.93 4.5*	NHT:0.26 NHT:15.0* NTK:1.15 NTK:18.0*	0.004 0.032*	<	Zn 0.004

[1] - data are long-term medians unless specified
* - maximum for period of record
** - minimum for period of record
< - below detection limits

BOD - Biological Oxygen Demand
RST - Total Dissolved Solids
NHT - Ammonia/Ammonium
Hg - Mercury
As - Arsenic

SO_4 - Total Sulphates
RSP - Suspended Solids
NTK - Total Kjeldahl Nitrogen
Zn - Zinc

Table 2: Selected water quality data[1] for Upper Black River and Fox Creek

Station	Chlorides mg/ℓ	Conduct-ivity us	pH	Sulphates mg/ℓ	Total Phosphorus mg/ℓ	Total Ammonia mg/ℓ	Zinc mg/ℓ	Copper mg/ℓ	Iron mg/ℓ	Chromium mg/ℓ
Upper Black River (-0060-006-)	0.3	178 393*	7.4 8.1* 6.7**	2 32*	0.011	0.02 0.98*	0.002 0.190* <**	0.001 0.049* <**	0.25 1.20* 0.089**	0.072*
D/S Mose Lake (-0060-004-)	2.3	262 1034*	7.5	48 489*	0.011	0.62 8.74*	0.010 0.580*	0.007 0.086*	0.44 2.10*	0.055*
at Hwy. 614 (-0060-003-)	1.2	234	7.8	15	0.010	0.06	0.028	0.004	0.27	0.160*
Fox Creek below Manitouwadge L. (-0060-005-)	3.4	260	7.4 8.1*	49 100* 6.8*	0.010 10**	0.05	0.352 1.800* 0.003**	0.018 0.130* < **	1.20 5.70* 0.10*	0.099*
Fox Creek above Manitouwadge L. (-0060-008-)	1.4	276	7.1 7.6* 6.0**	57 190* 5.1**	0.015	0.19	0.540 5.400* 0.110**	0.021 0.36* < **	3.00 23.00* < **	0.044*

1 - data are long-term medians unless specified
* - maximum for period of record
** - minimum for period of record
< - below detection limits

Table 3: Selected water quality data from Blackbird Creek.

		BOD mg/ℓ	Conductivity umhos/cm	Dissolved Oxygen mg/ℓ	pH	Suspended Solids mg/ℓ	Total Phos. mg/ℓ	Total Ammonia mg/ℓ
Blackbird Creek	median	180	1425	3.95	7.2	90	0.26	1.7
(-0074-001-)	max.	610	3010	14.9	11.2	3230	3.300	7.10
	min.	1	194	0.0	2.5	10	0.022	0.15

Table 4 Selected water quality parameters (median values) in major tributaries on the North Shore of Lake Superior.

Station	Flow* m^3/s	Alkalinity mg/ℓ	Conductivity µS	pH	Suspended Solids mg/ℓ	Total Phosphorus mg/ℓ	Organic Nitrogen mg/ℓ	Zinc mg/ℓ	Copper mg/ℓ	Iron mg/ℓ	Aluminum mg/ℓ
White River (-0057-001-)	—	65	146	7.6	1	0.009	0.03	0.002	0.001	0.14	0.06
Pic River (-0060-001-)	64.6	98	184	8.0	60	0.045	0.44	0.006	0.004	0.95	1.56
Little Pic. R. (-0067-001-)	18.9	82	167	8.0	35	0.037	0.46	0.005	0.003	1.20	0.98
Nipigon R. (-0090-002-)	331	72	145	7.9	3	0.008	0.20	0.0005	0.002	0.15	0.11
Black Sturgeon R. (-0092-001-)	18.8	59	216	7.7	5	0.013	0.41	0.002	0.004	0.35	0.14

* annual mean discharge (Environment Canada 1989)

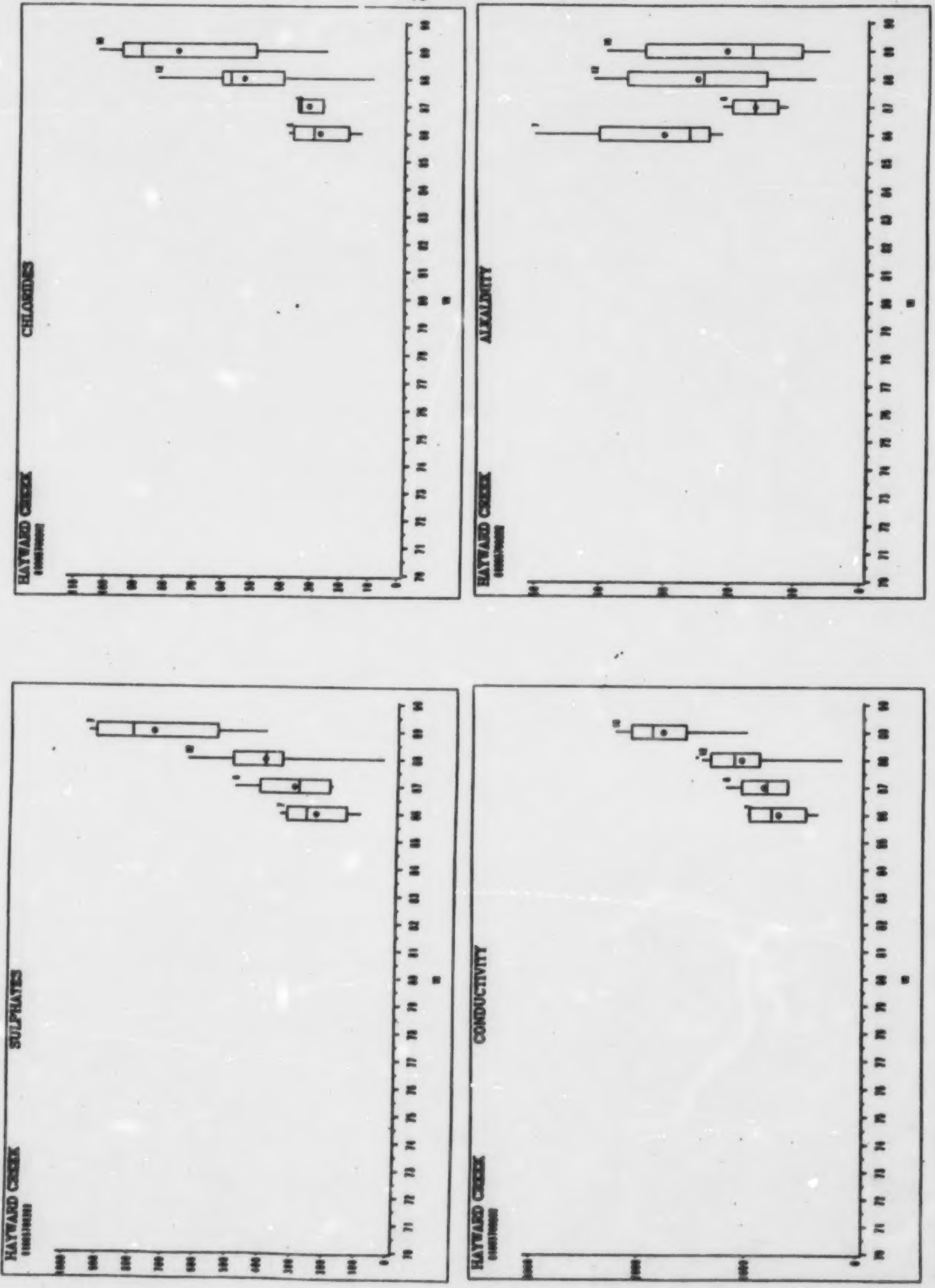

Fig. 4. Water quality in Hayward Creek.

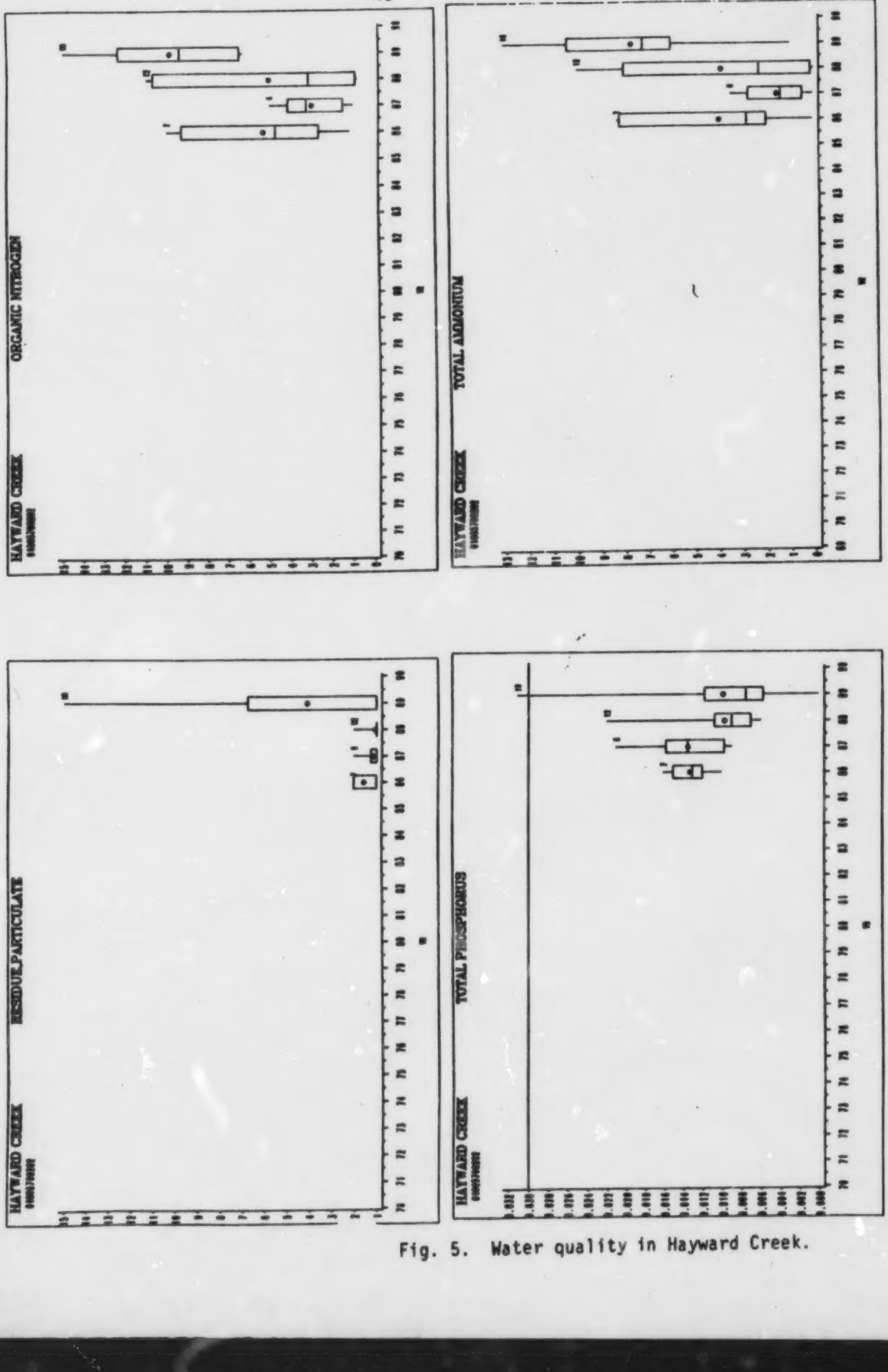

Fig. 5. Water quality in Hayward Creek.

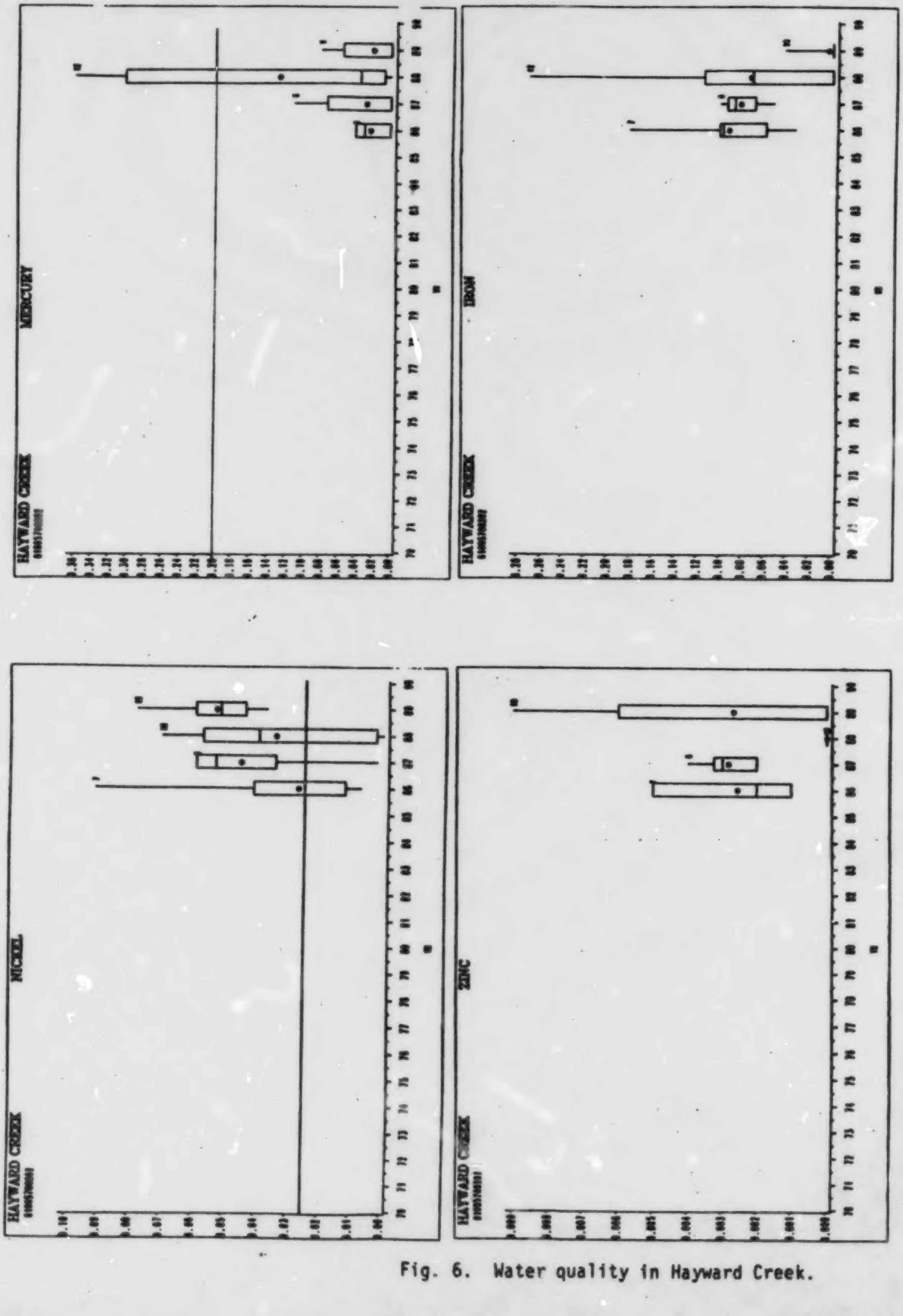

Fig. 6. Water quality in Hayward Creek.

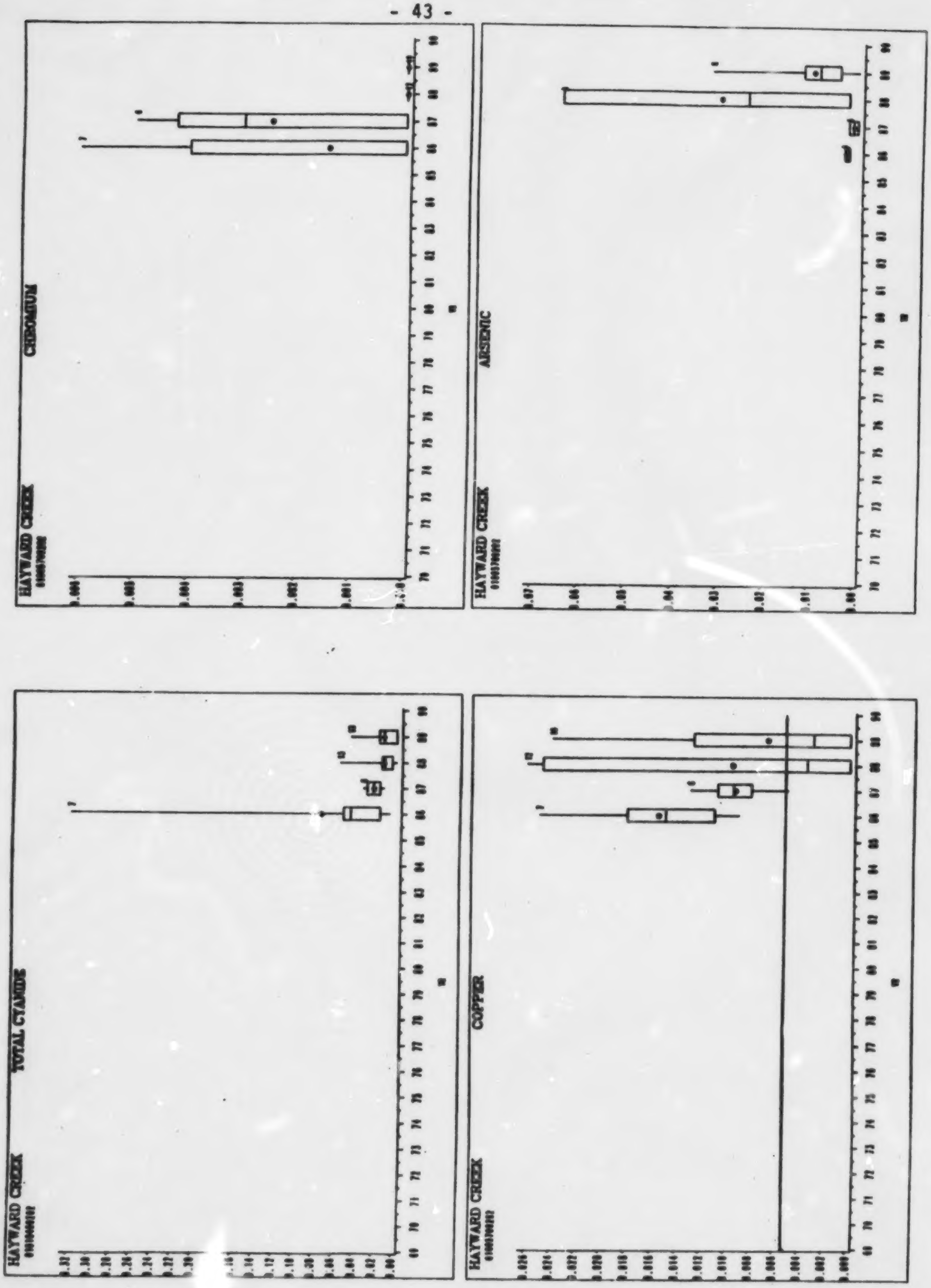

Fig. 7. Water quality in Hayward Creek.

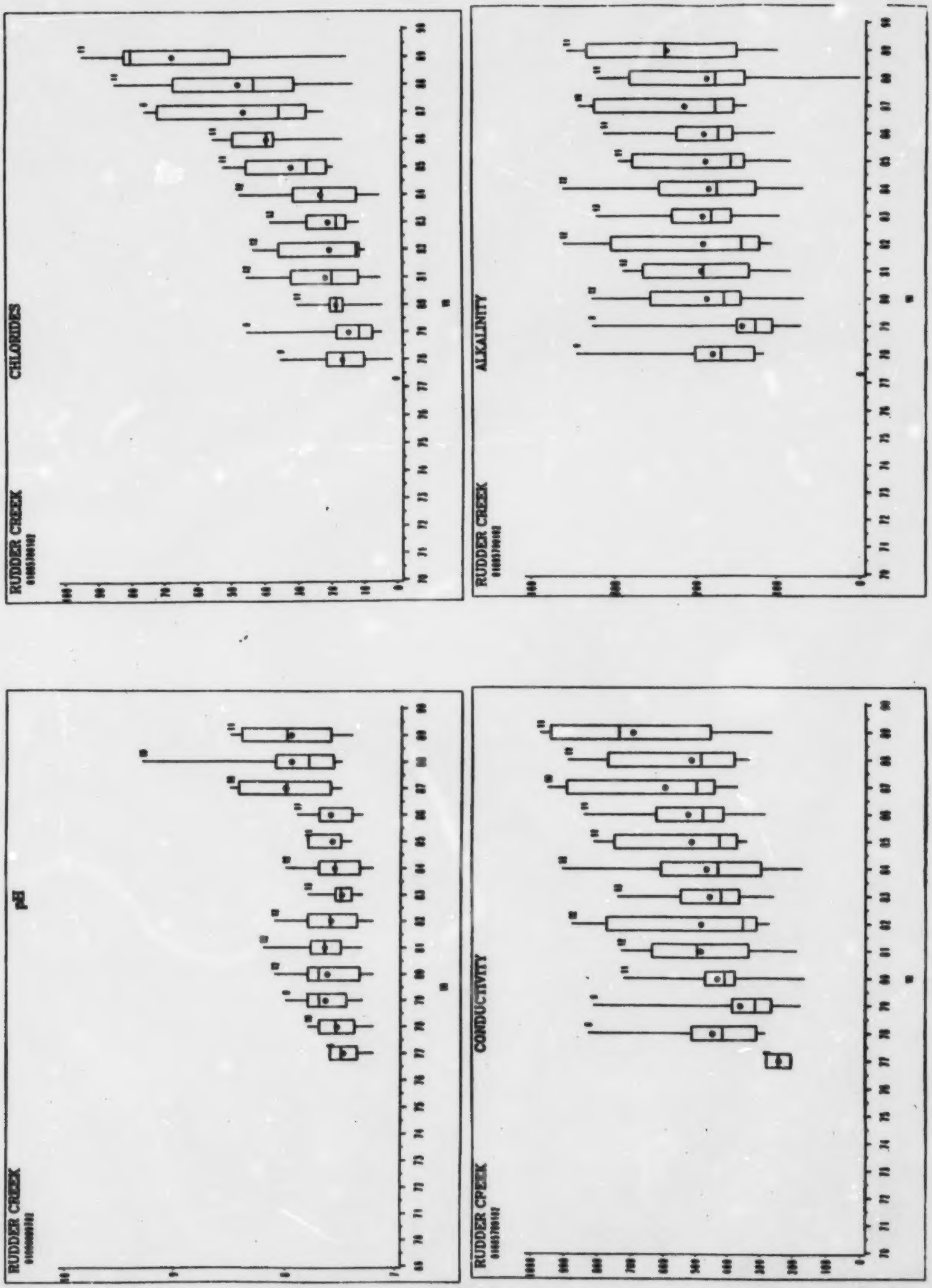

Fig. 8. Water quality in Rudder Creek.

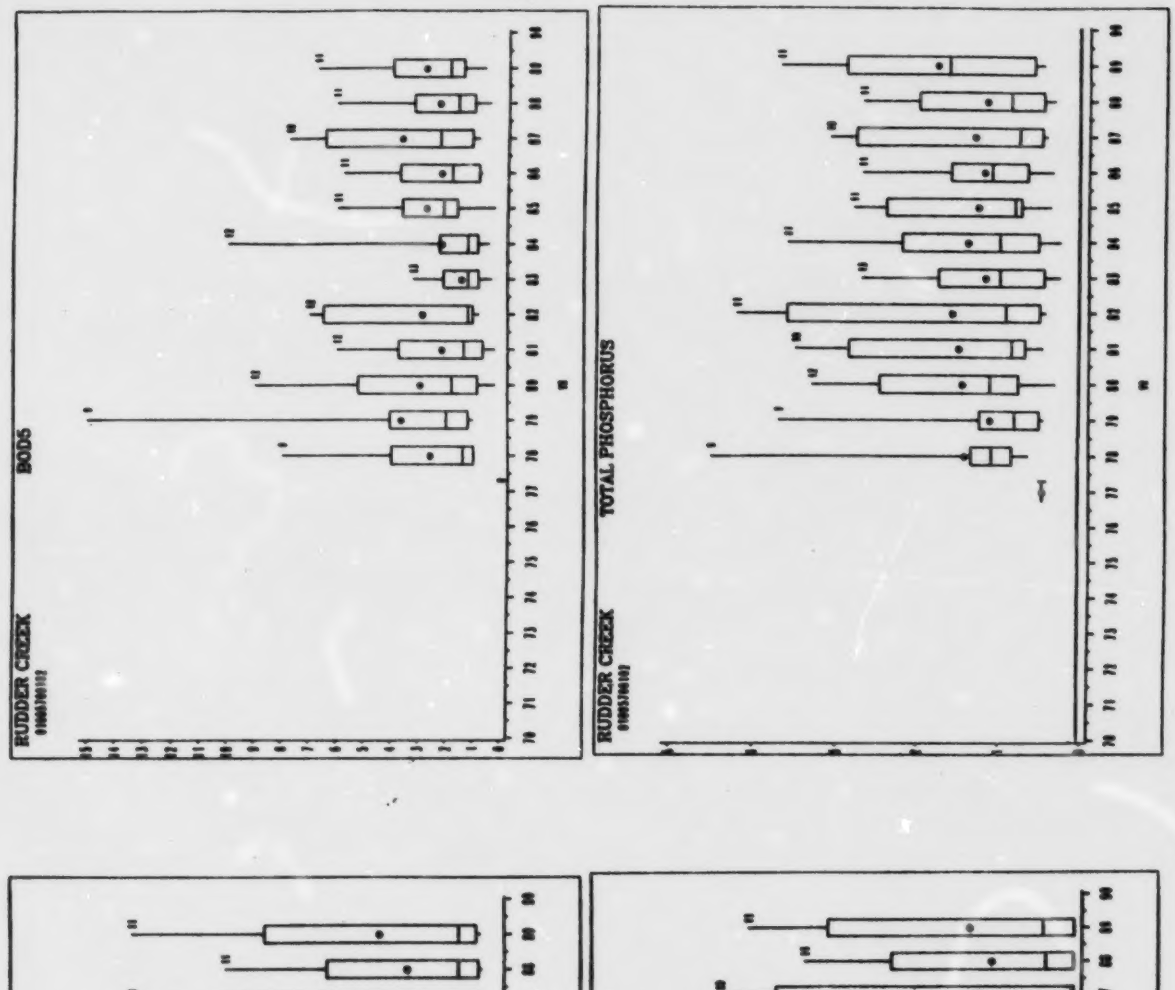

Fig. 9. Water quality in Rudder Creek.

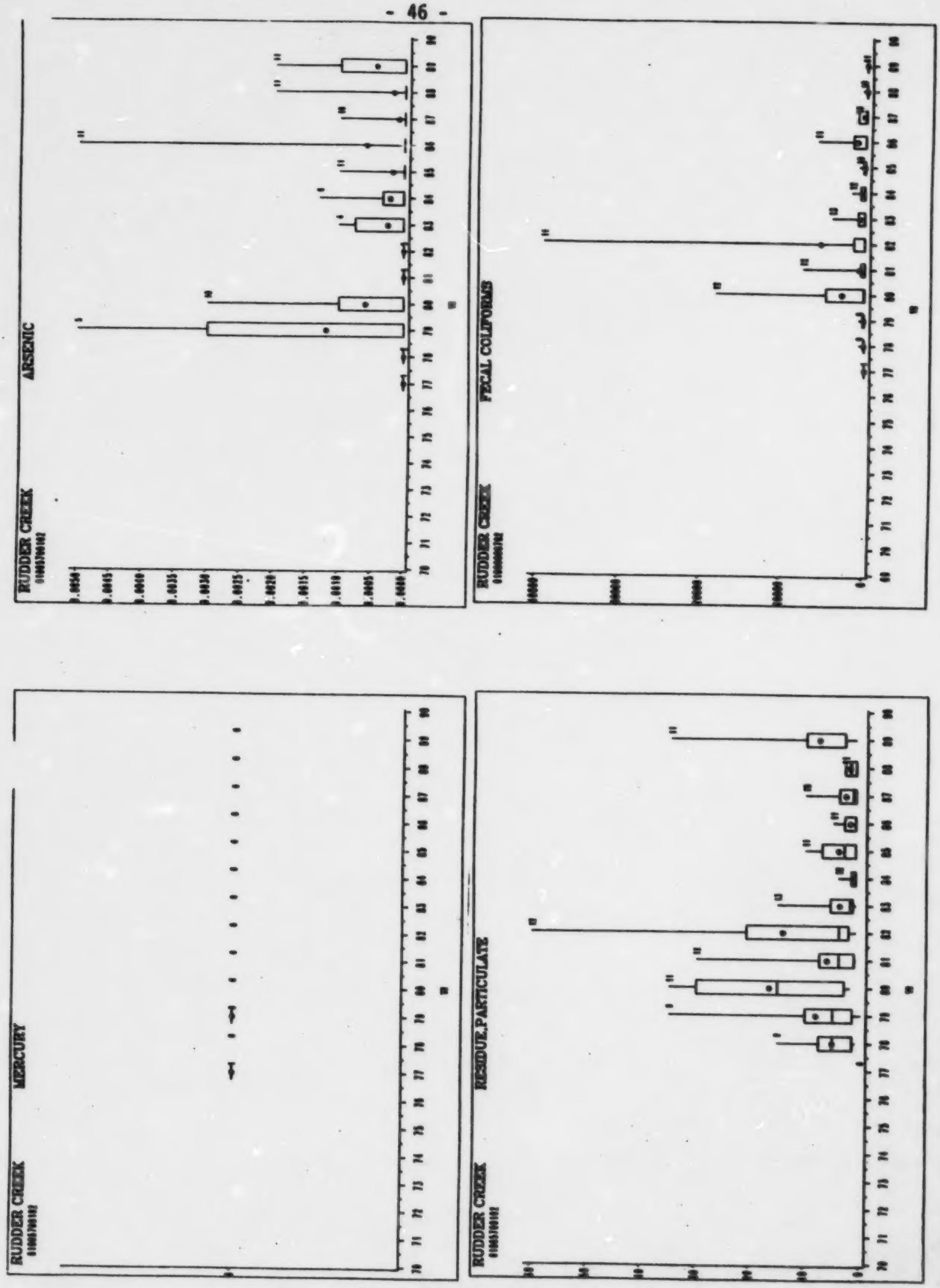

Fig. 10. Water quality in Rudder Creek.

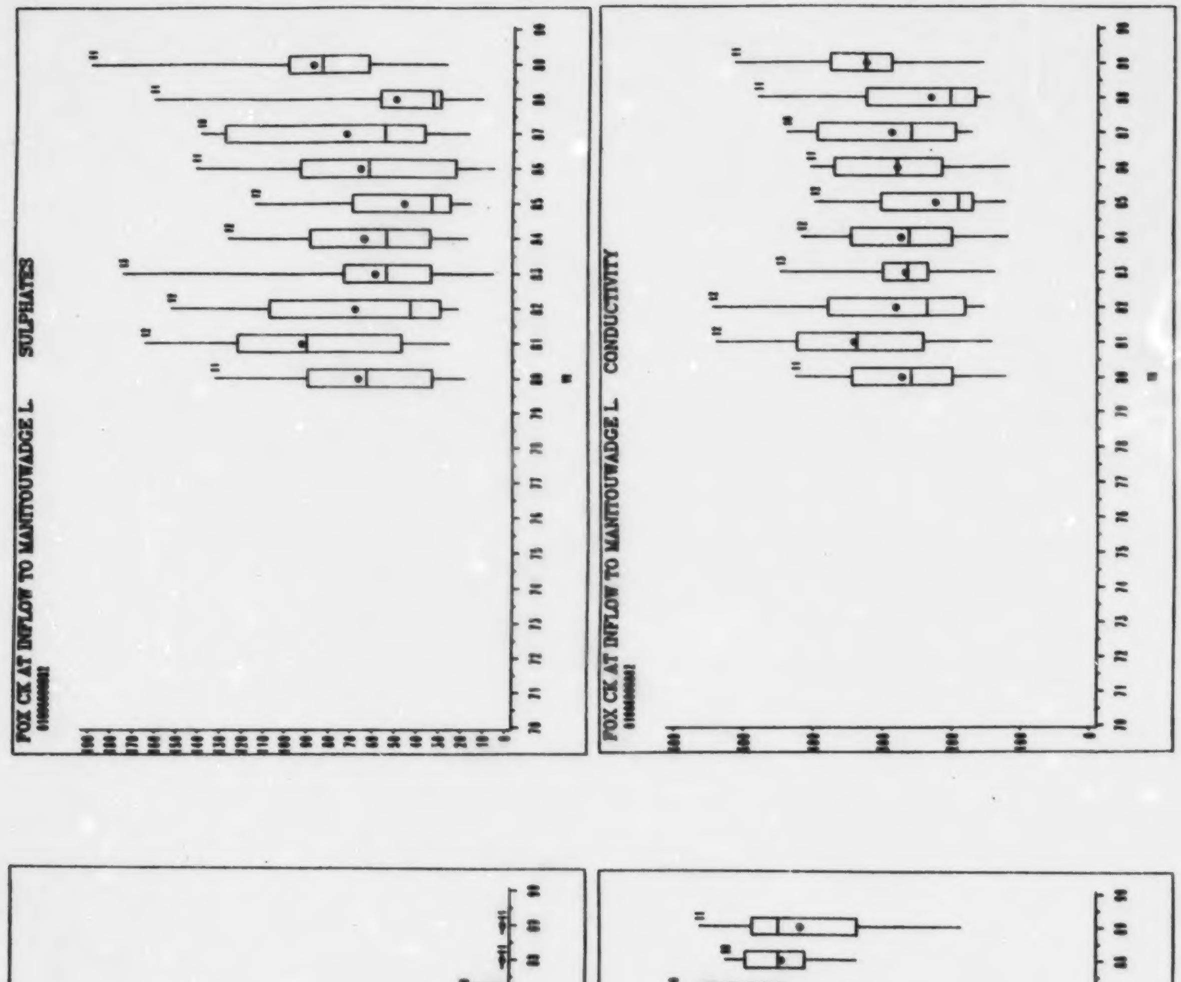

Fig. 11. Water quality in Fox Creek above Manitouwadge.

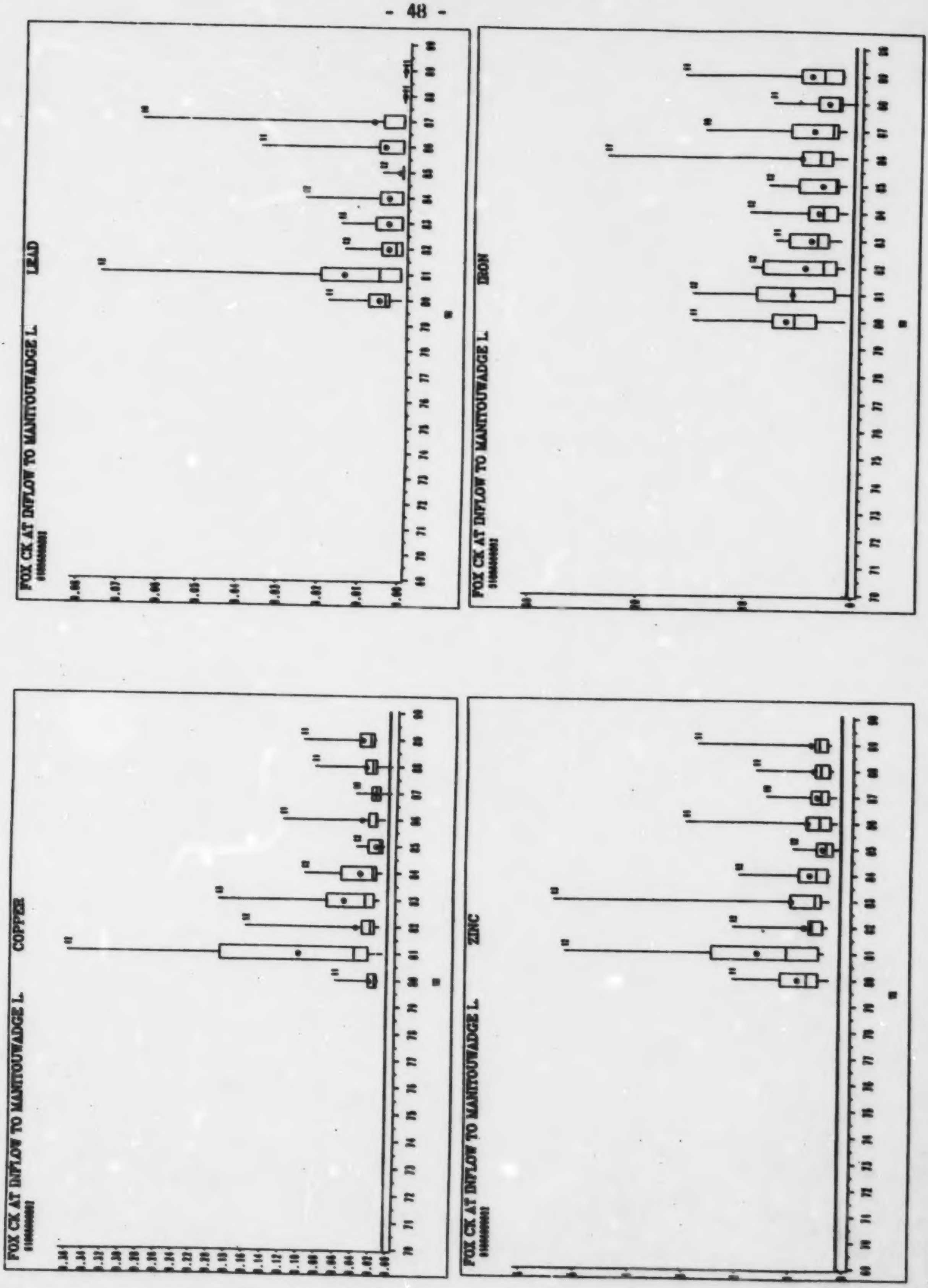

Fig. 12. Water quality in Fox Creek above Manitouwadge.

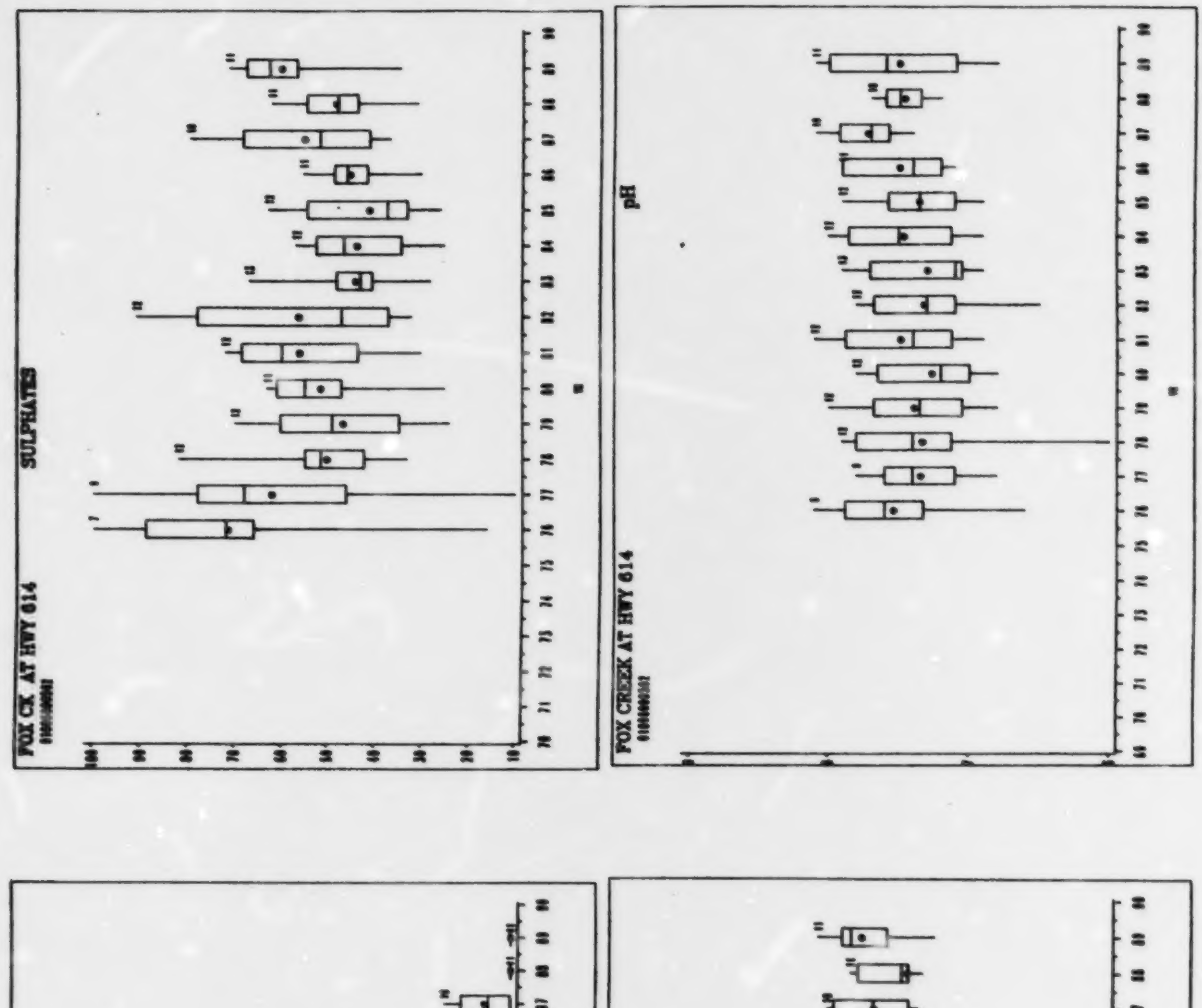

Fig. 13. Water quality in Fox Creek at Hwy. 614.

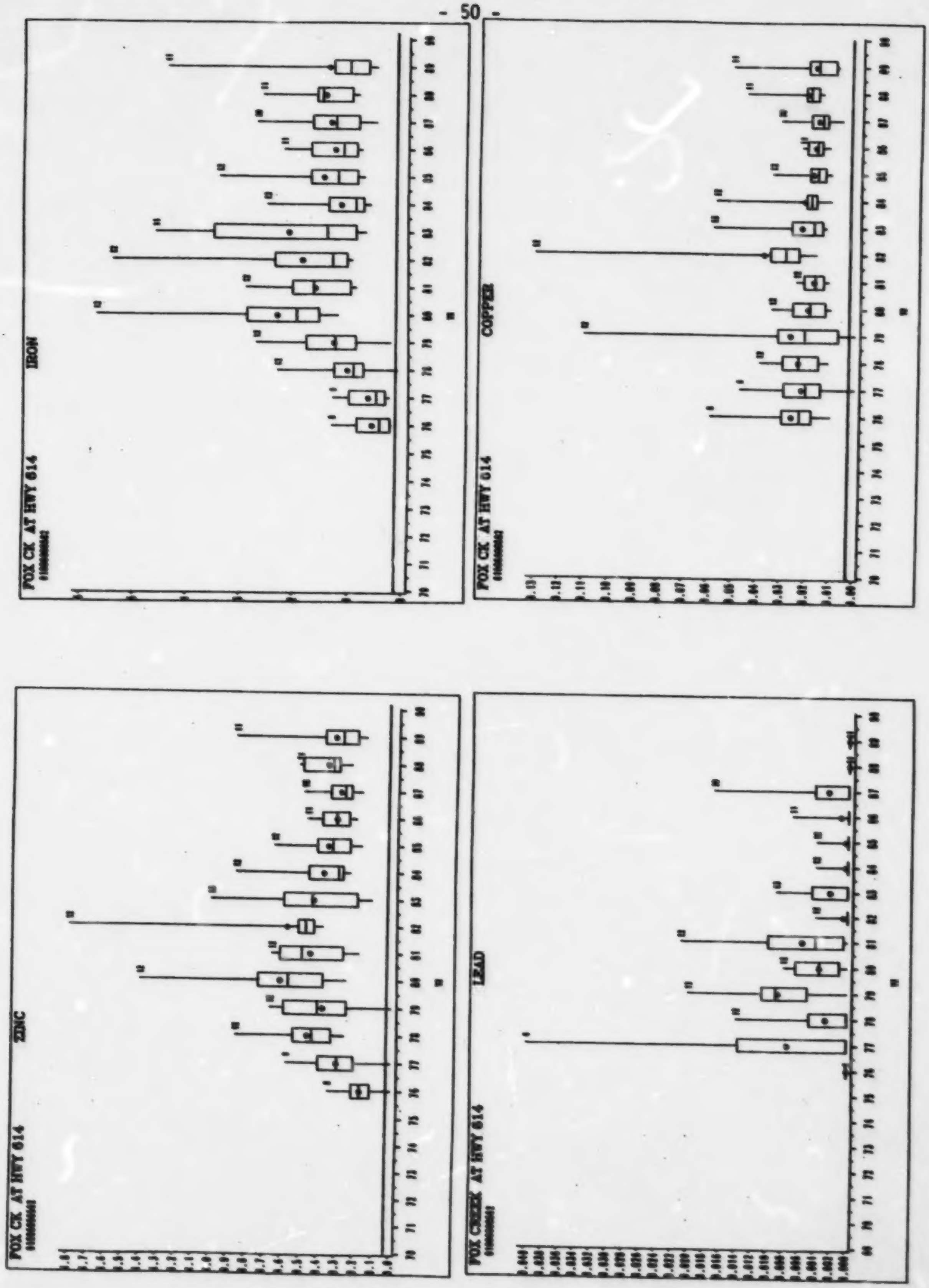

Fig. 14. Water quality in Fox Creek at Hwy. 614.

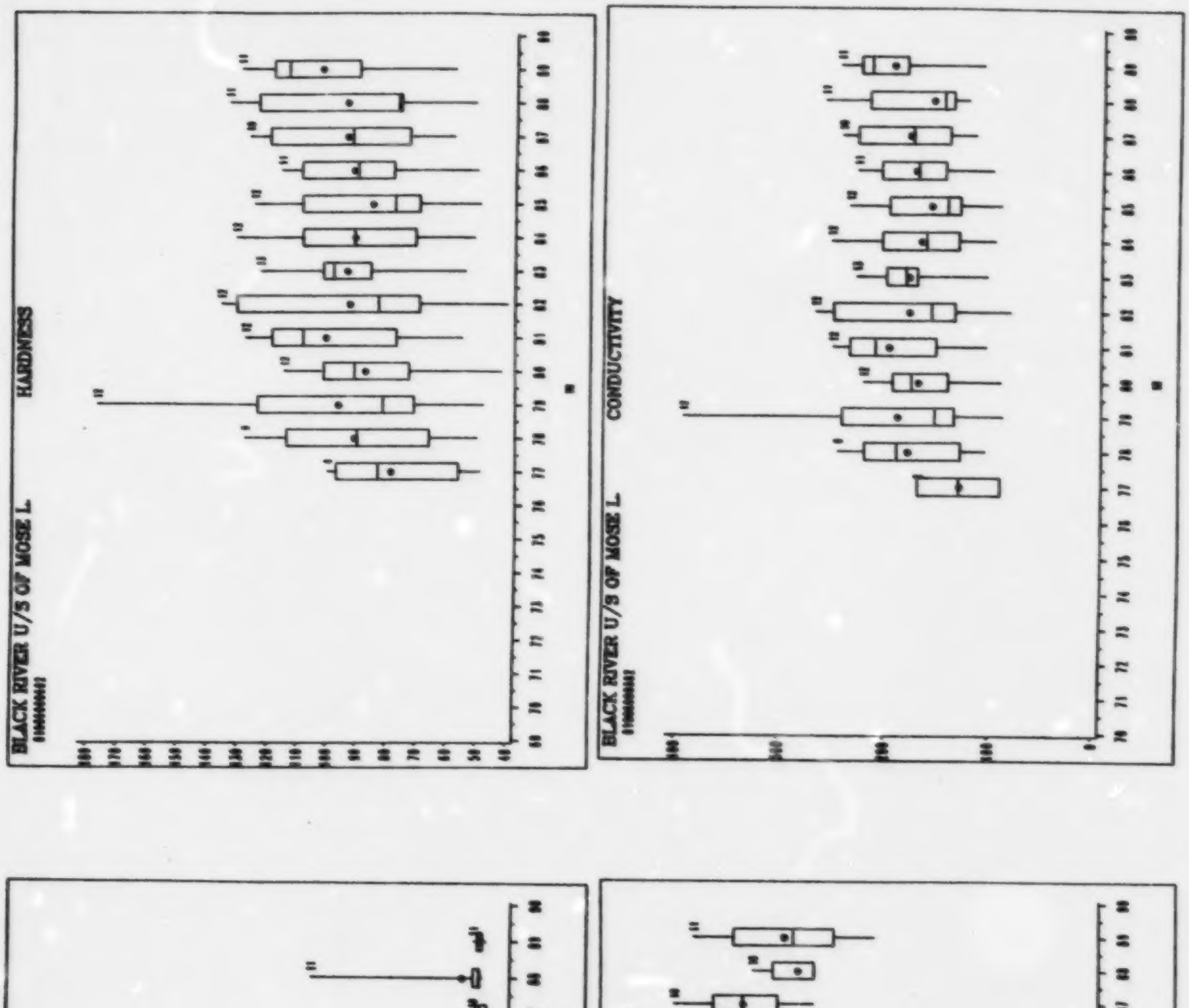

Fig. 15. Water quality in Upper Black River, U/S of Mose L.

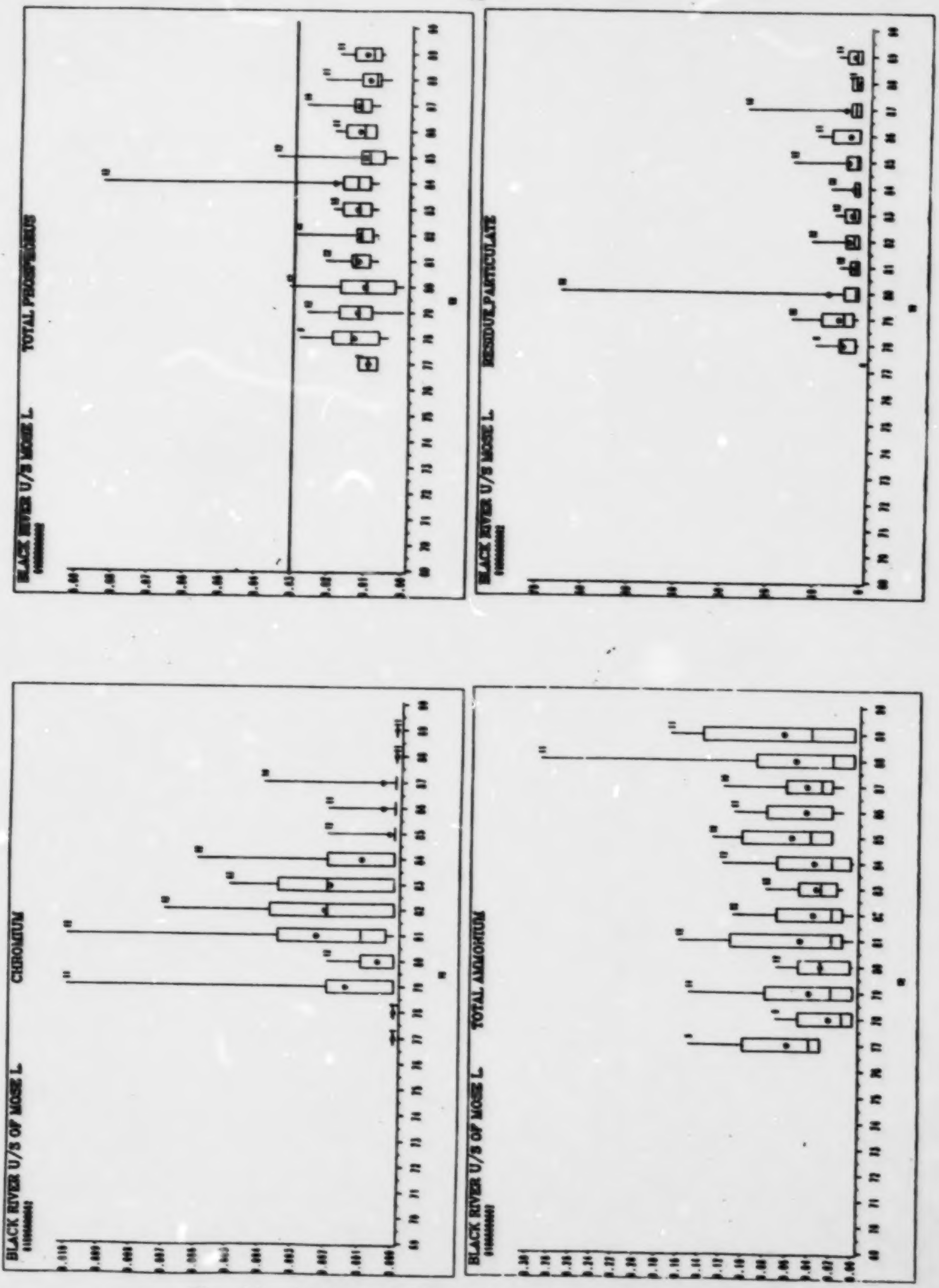

Fig. 16. Water quality in Upper Black River, U/S of Mose L.

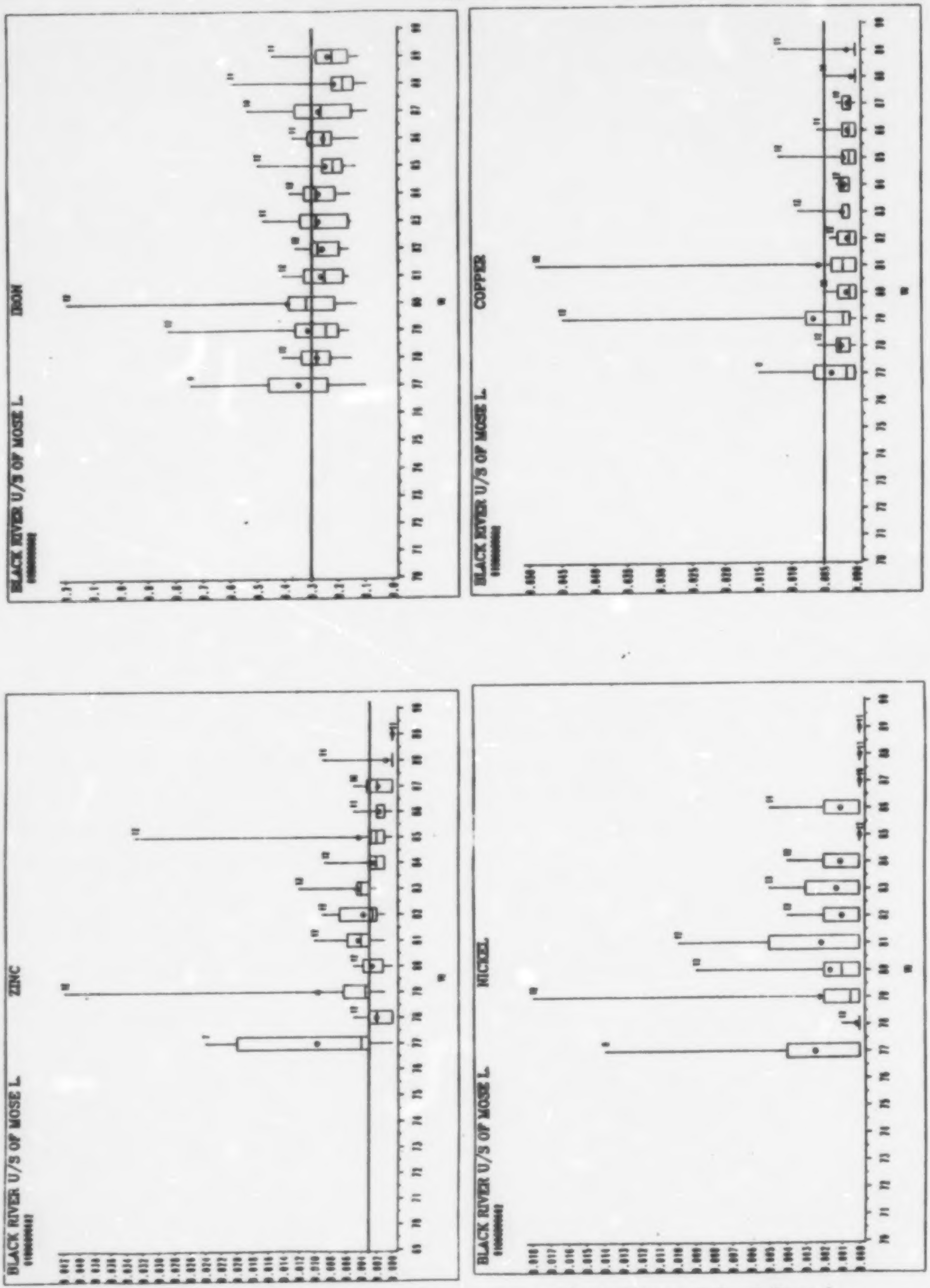

Fig. 17. Water quality in Upper Black River, U/S of Mose L.

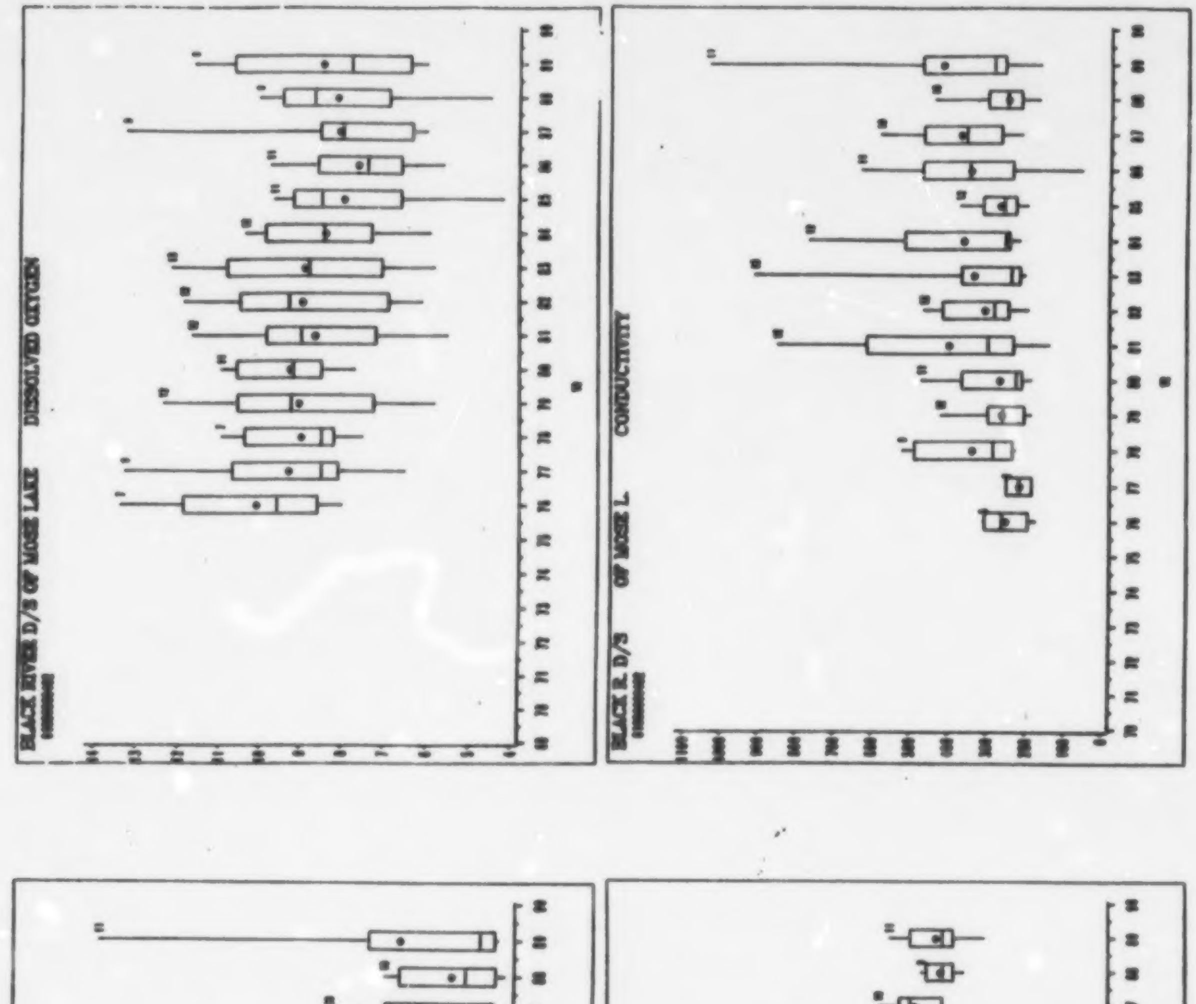

Fig. 18. Water quality D/S of Mose L.

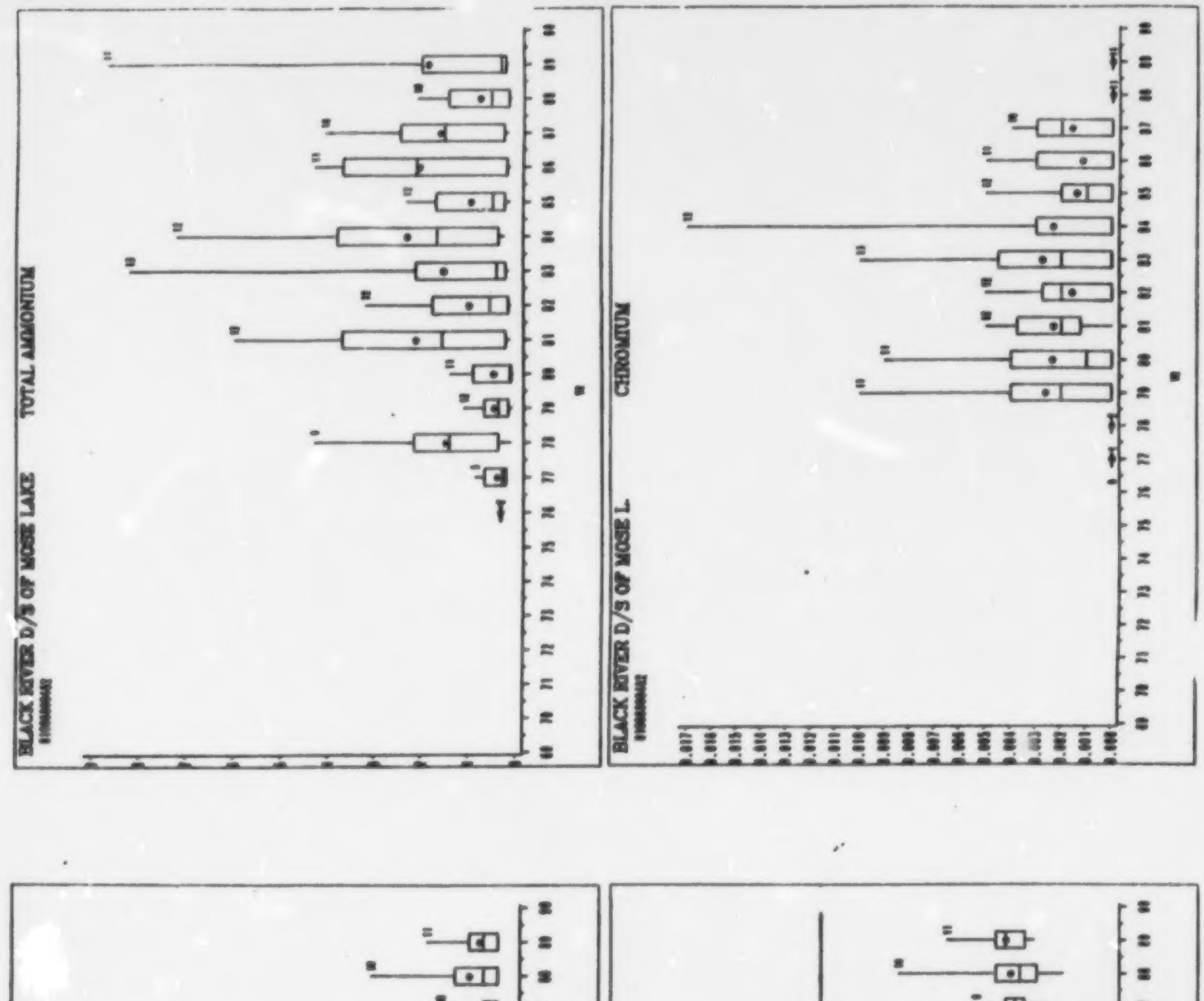

Fig. 19. Water quality D/S of Mose L.

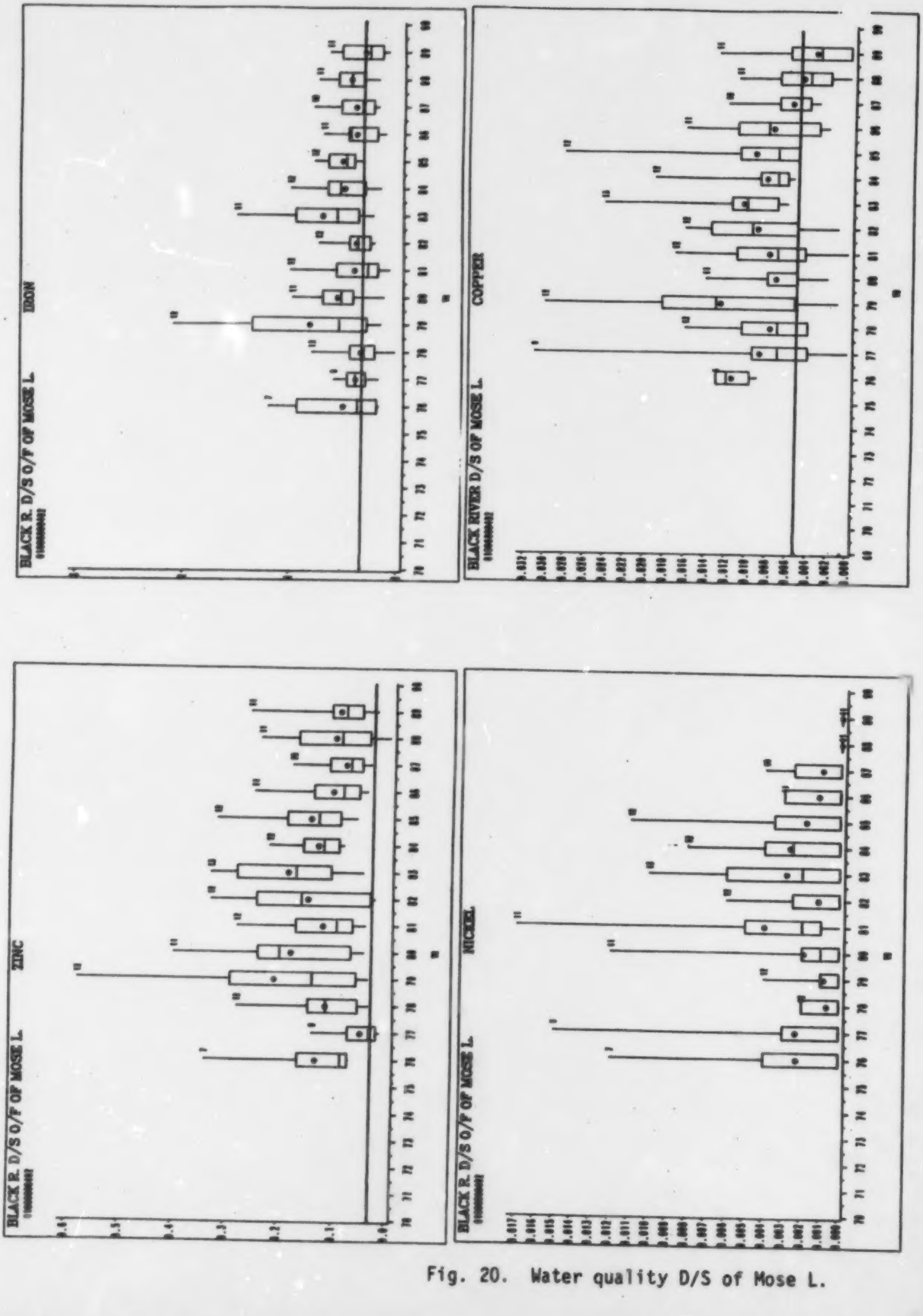

Fig. 20. Water quality D/S of Mose L.

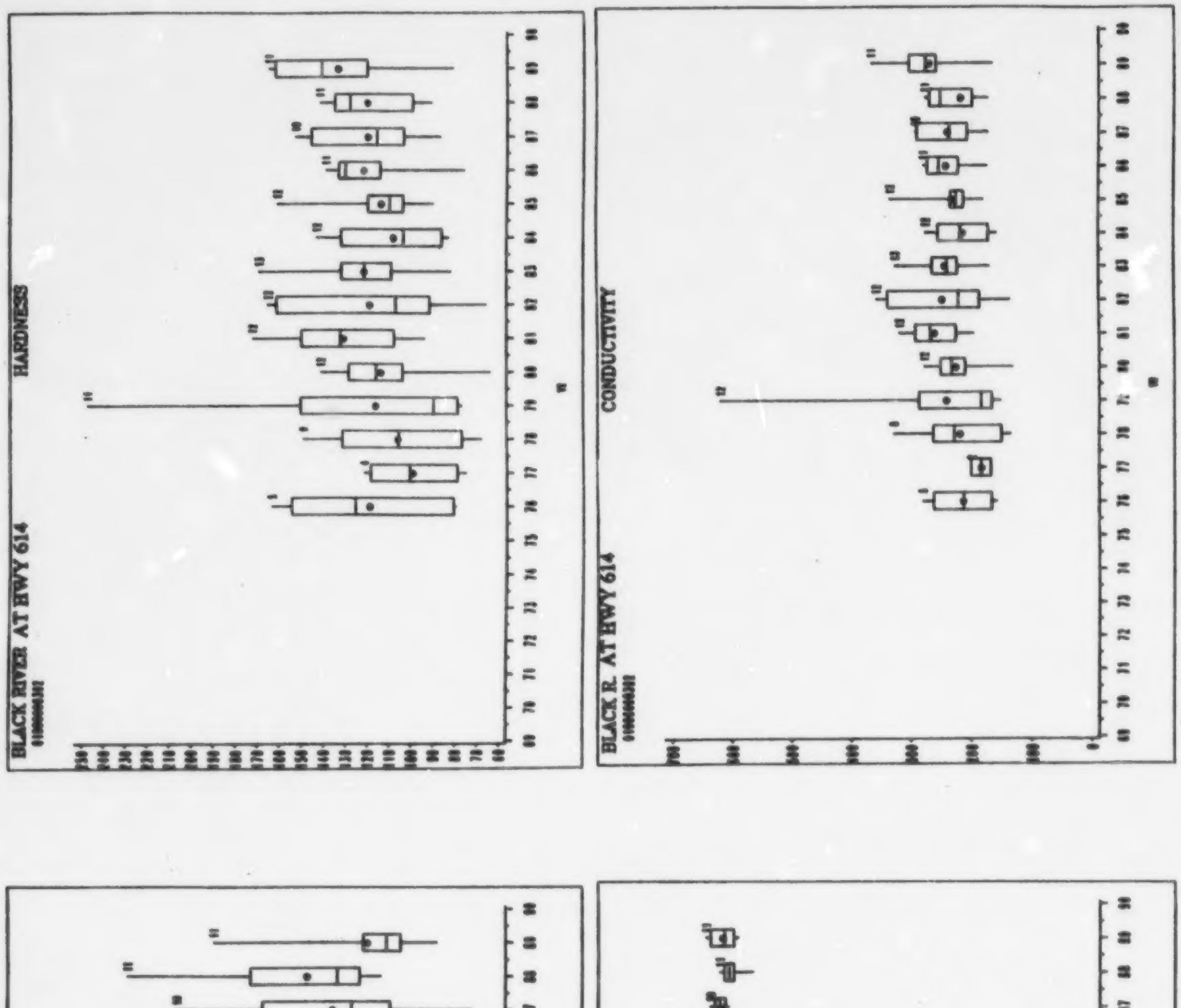

Fig. 21. Water quality in Black River at Hwy. 614.

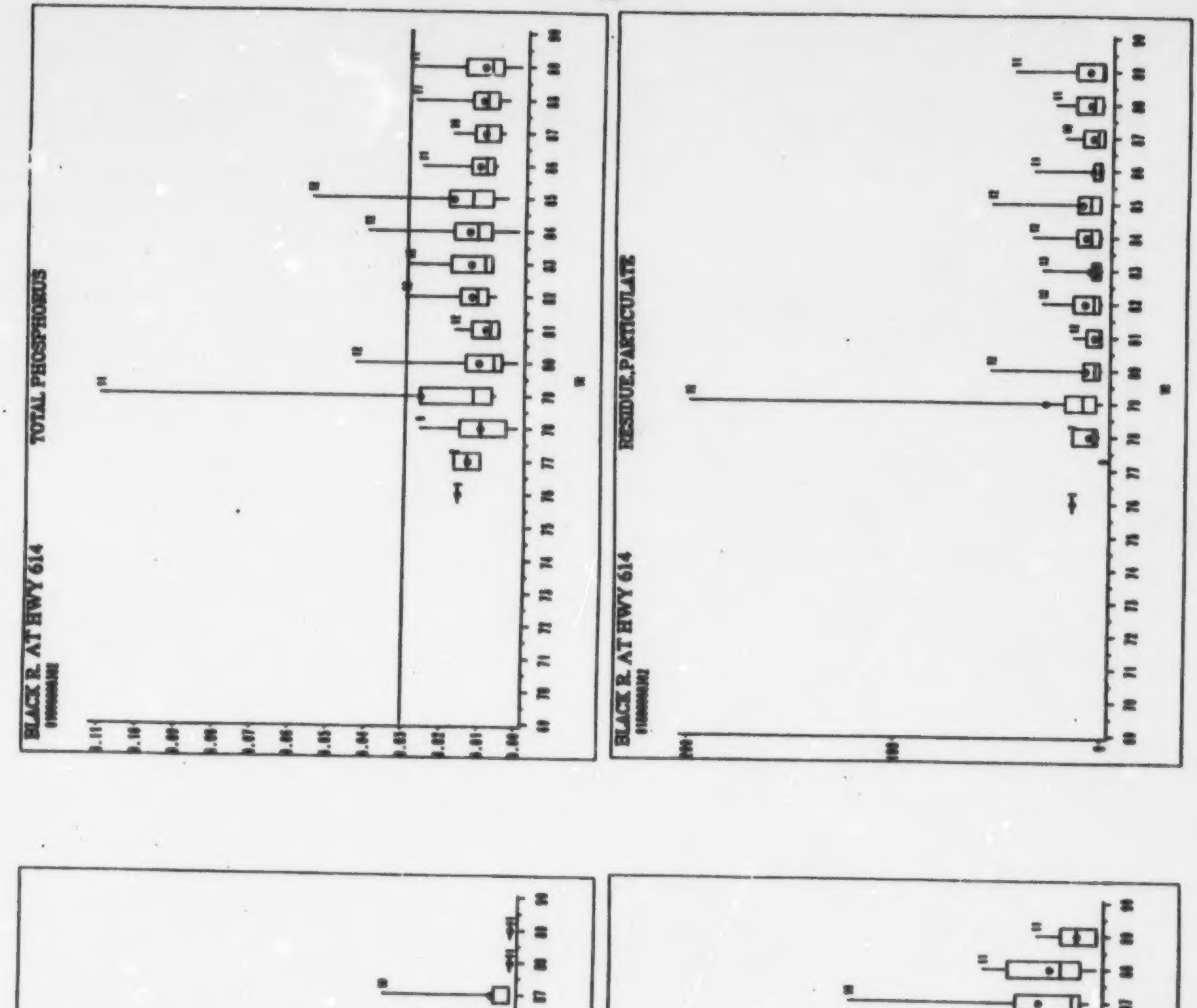

Fig. 22. Water quality in Black River at Hwy. 614.

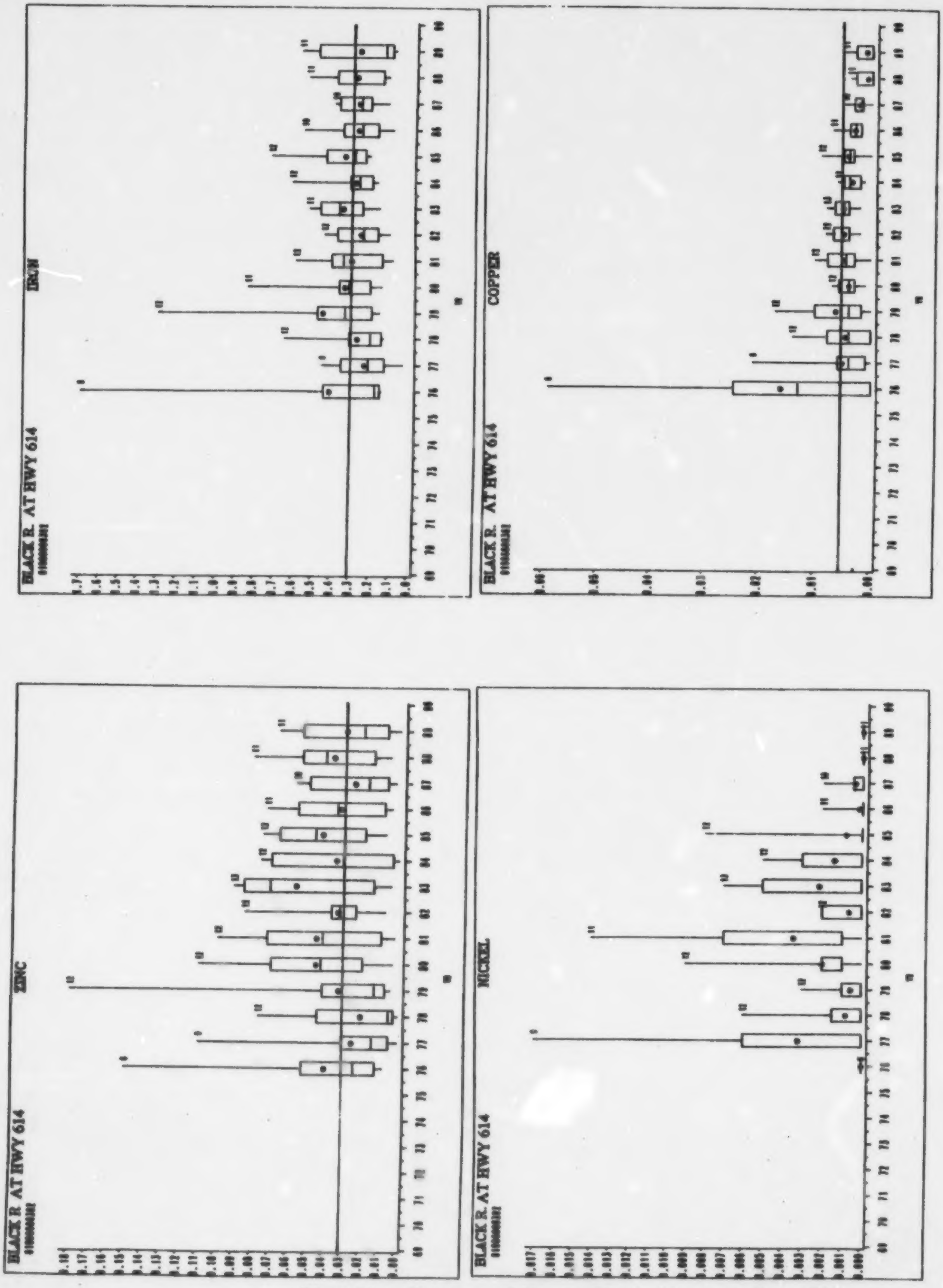

Fig. 23. Water quality in Black River at Hwy. 614.

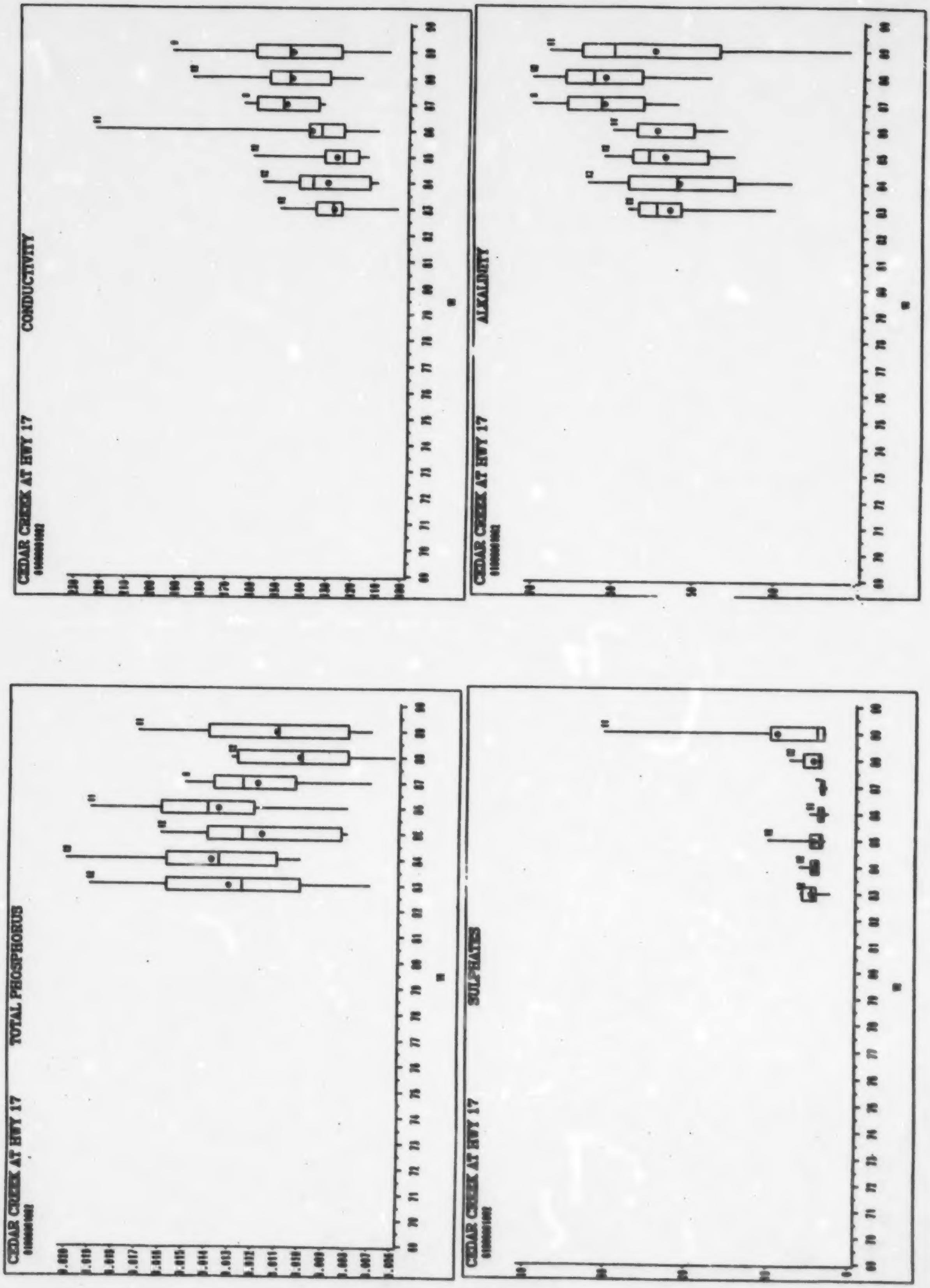

Fig. 24. Water quality in Cedar Creek at Hwy. 17.

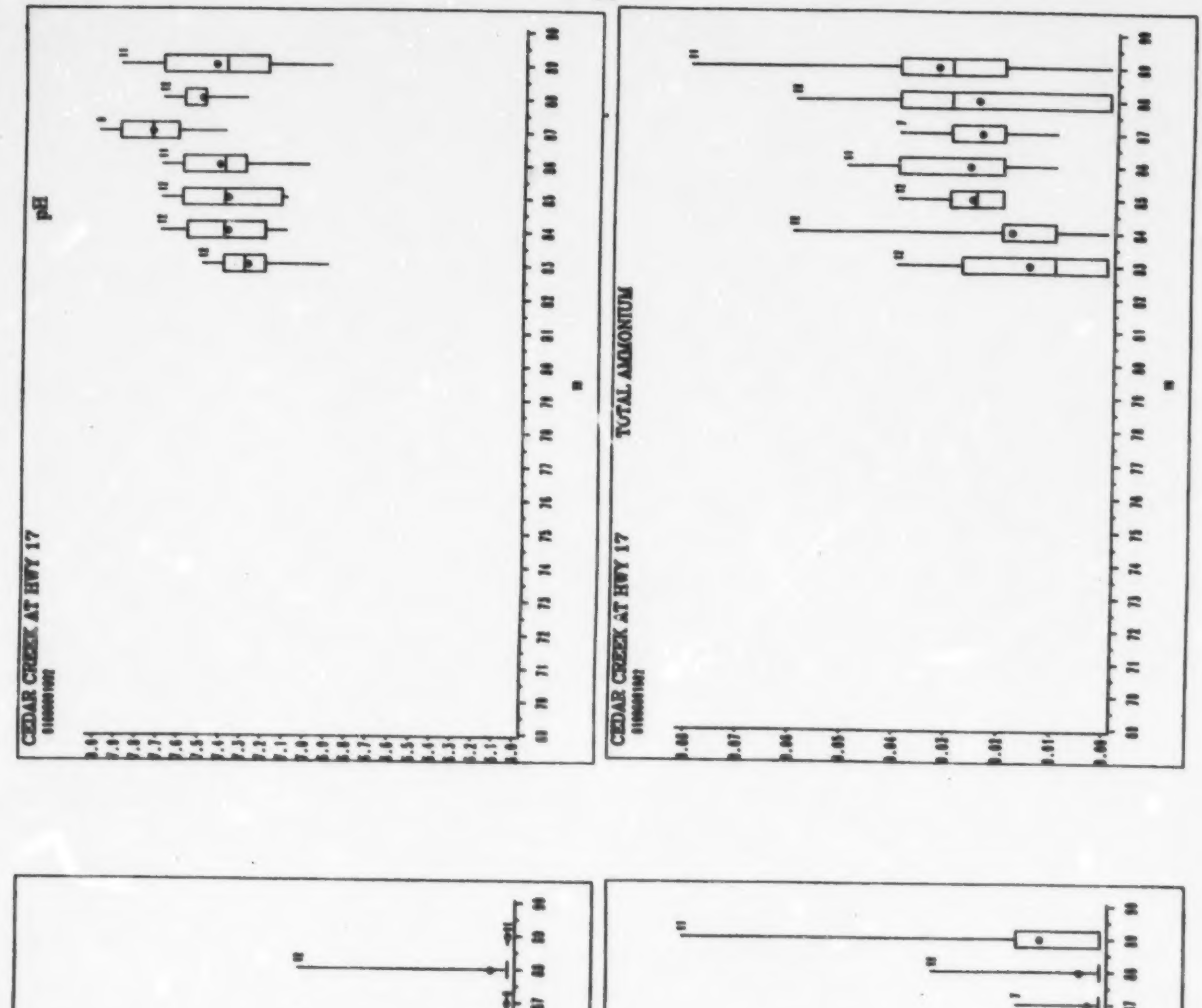

Fig. 25. Water quality in Cedar Creek at Hwy. 17.

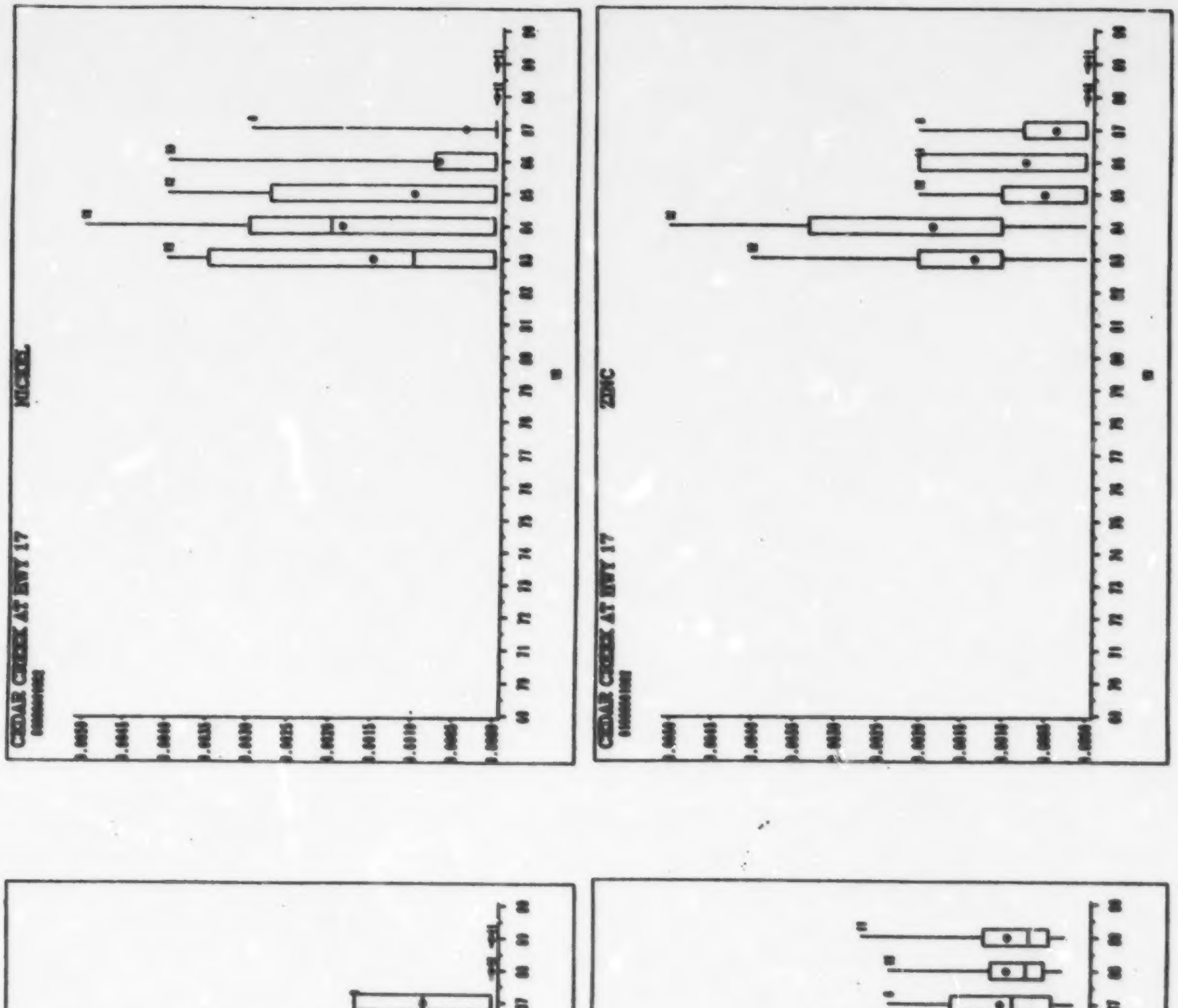

Fig. 26. Water quality in Cedar Creek at Hwy. 17.

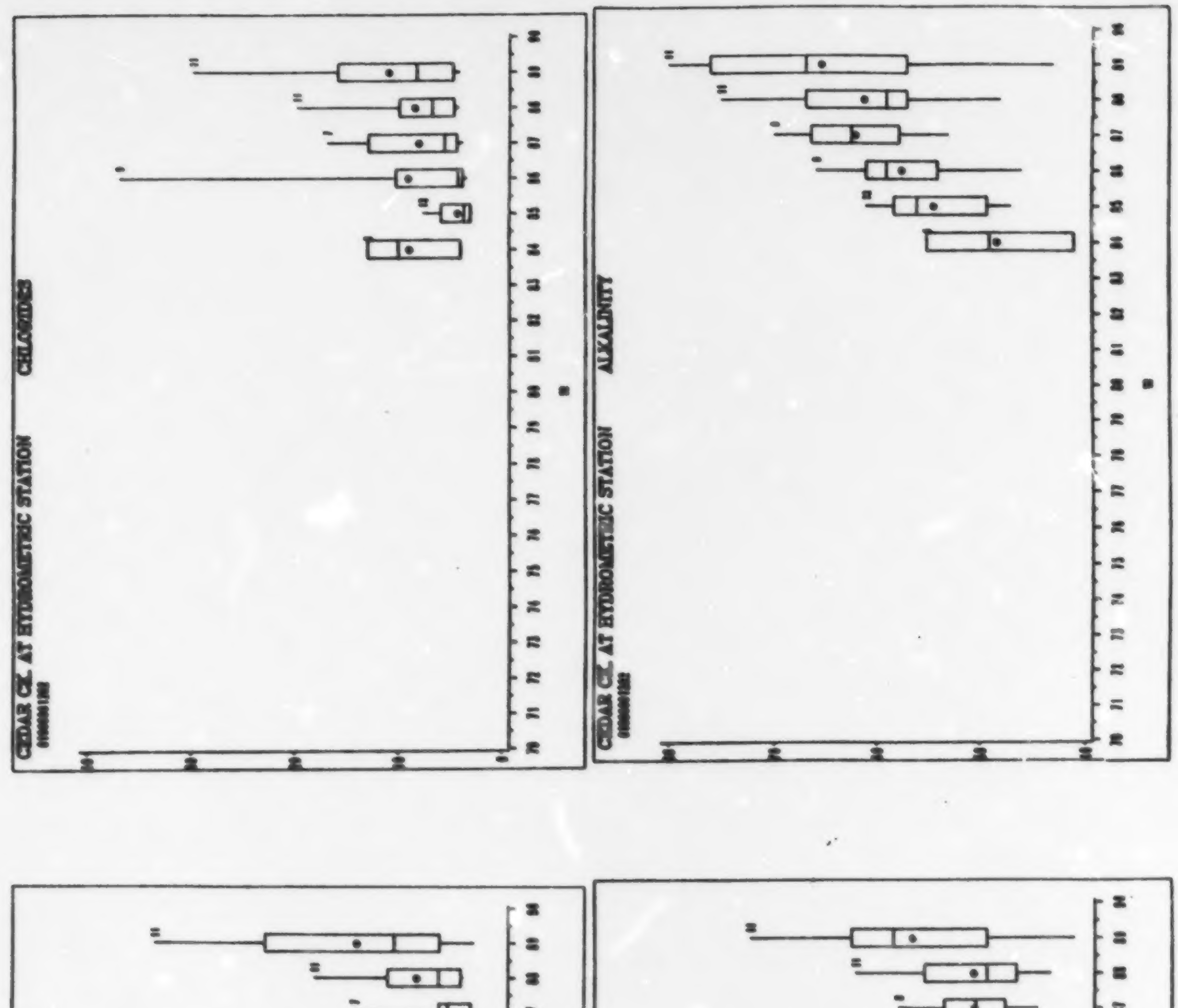

Fig. 27. Water quality in Cedar Creek at Hydrometric Station

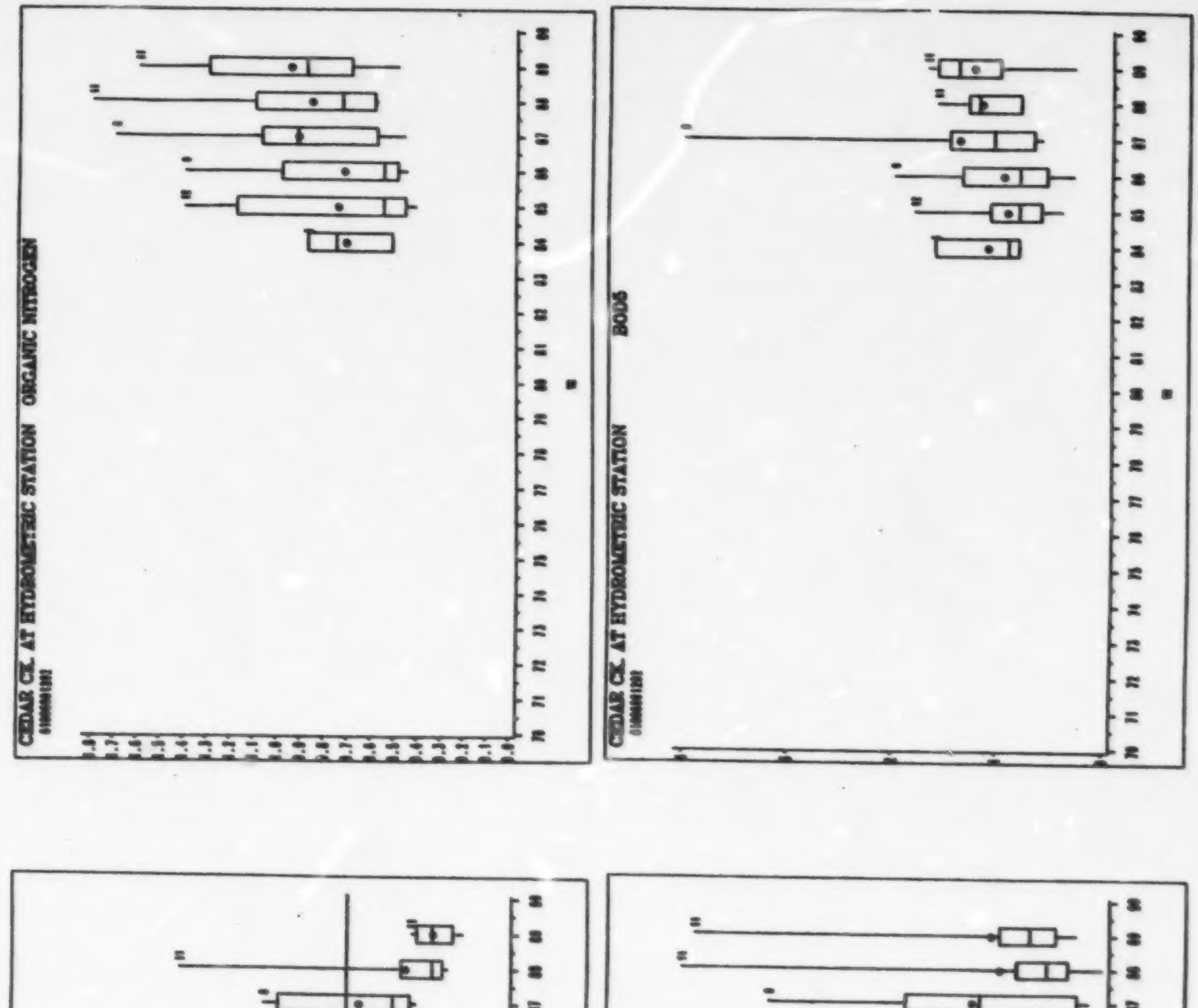

Fig. 28. Water quality in Cedar Creek at Hydrometric Station.

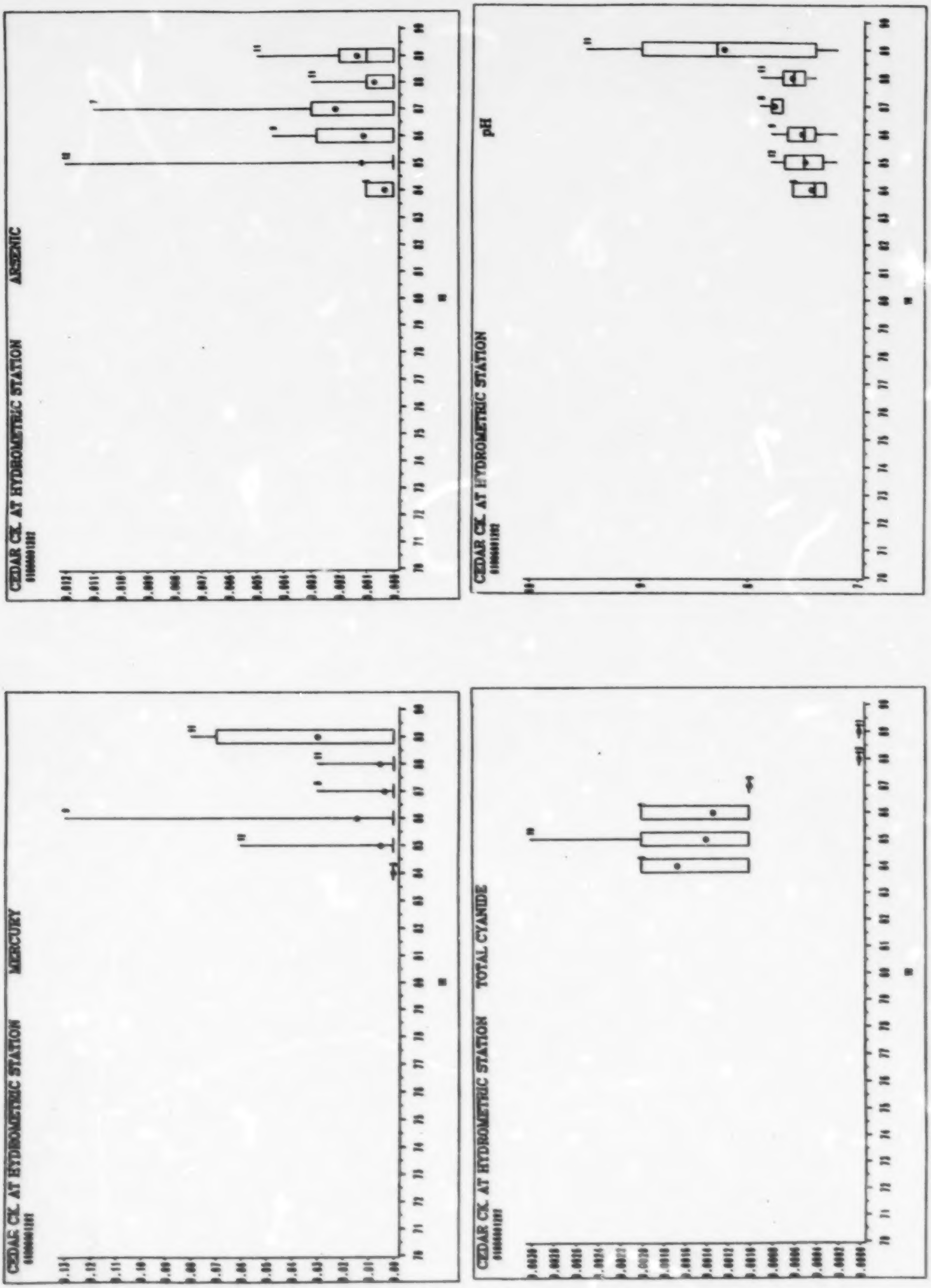

Fig. 29. Water quality in Cedar Creek at Hydrometric Station.

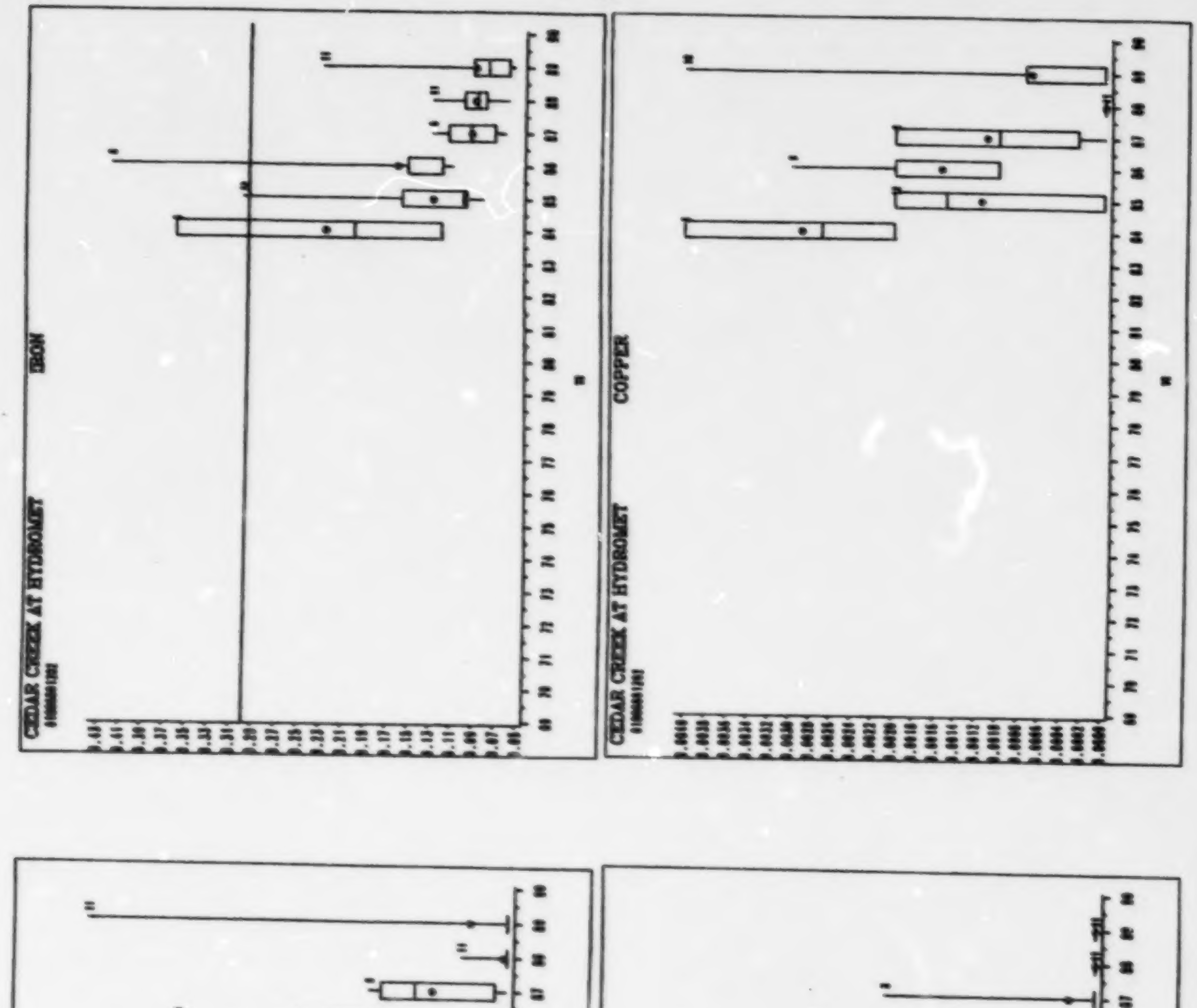

Fig. 30. Water quality in Cedar Creek at Hydrometric Station.

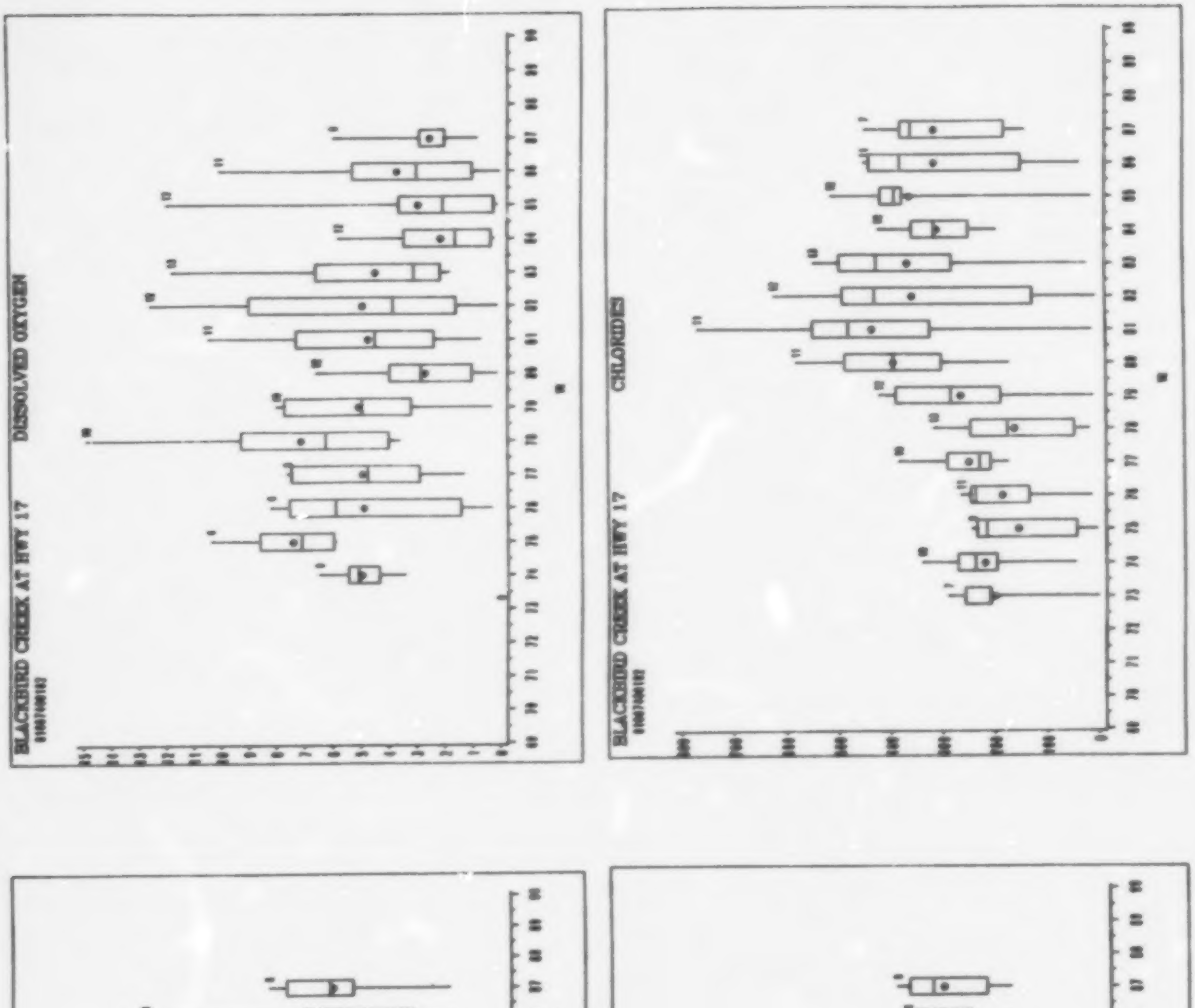

Fig. 31. Water quality in Blackbird Creek.

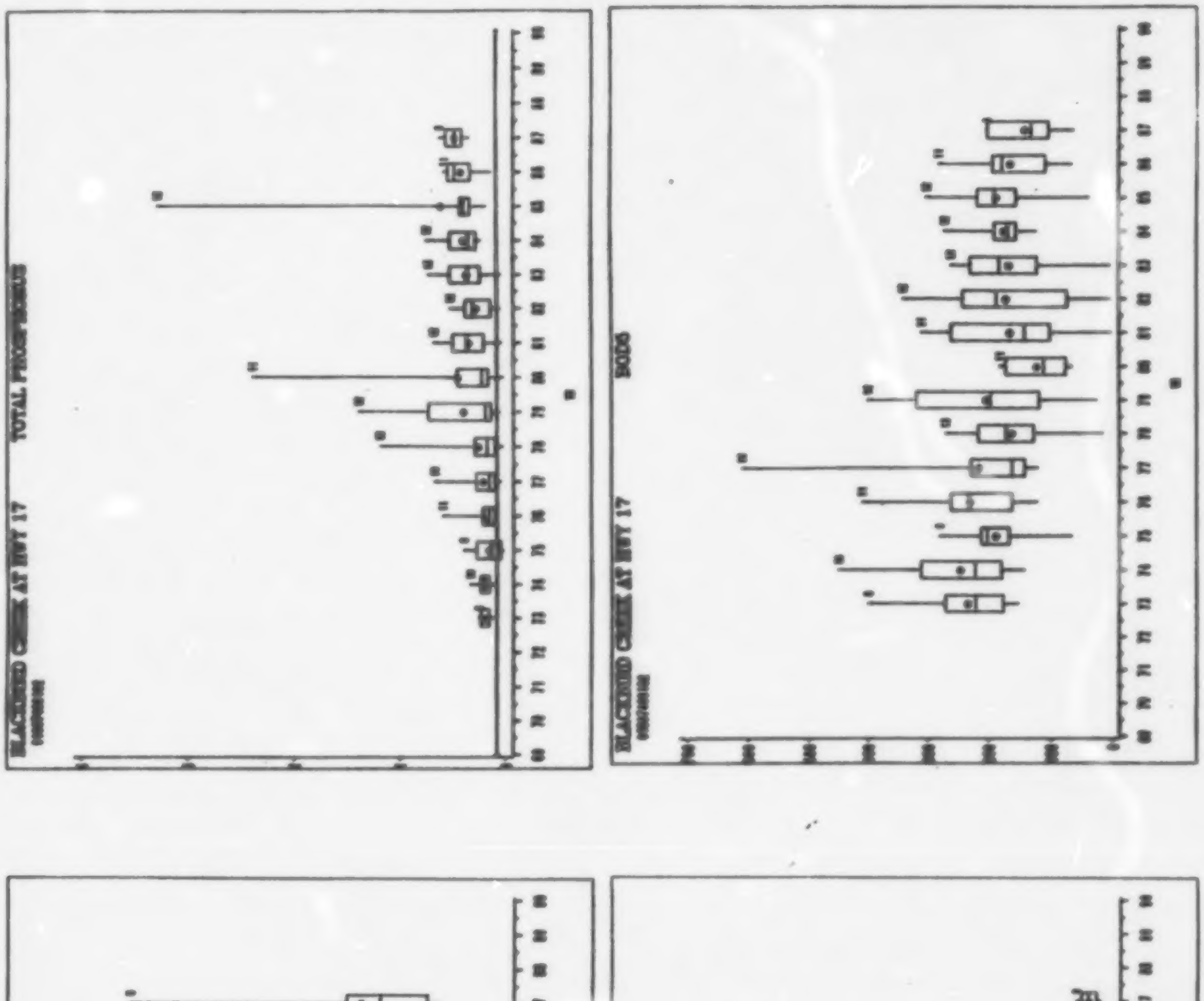

Fig. 32. Water quality in Blackbird Creek.

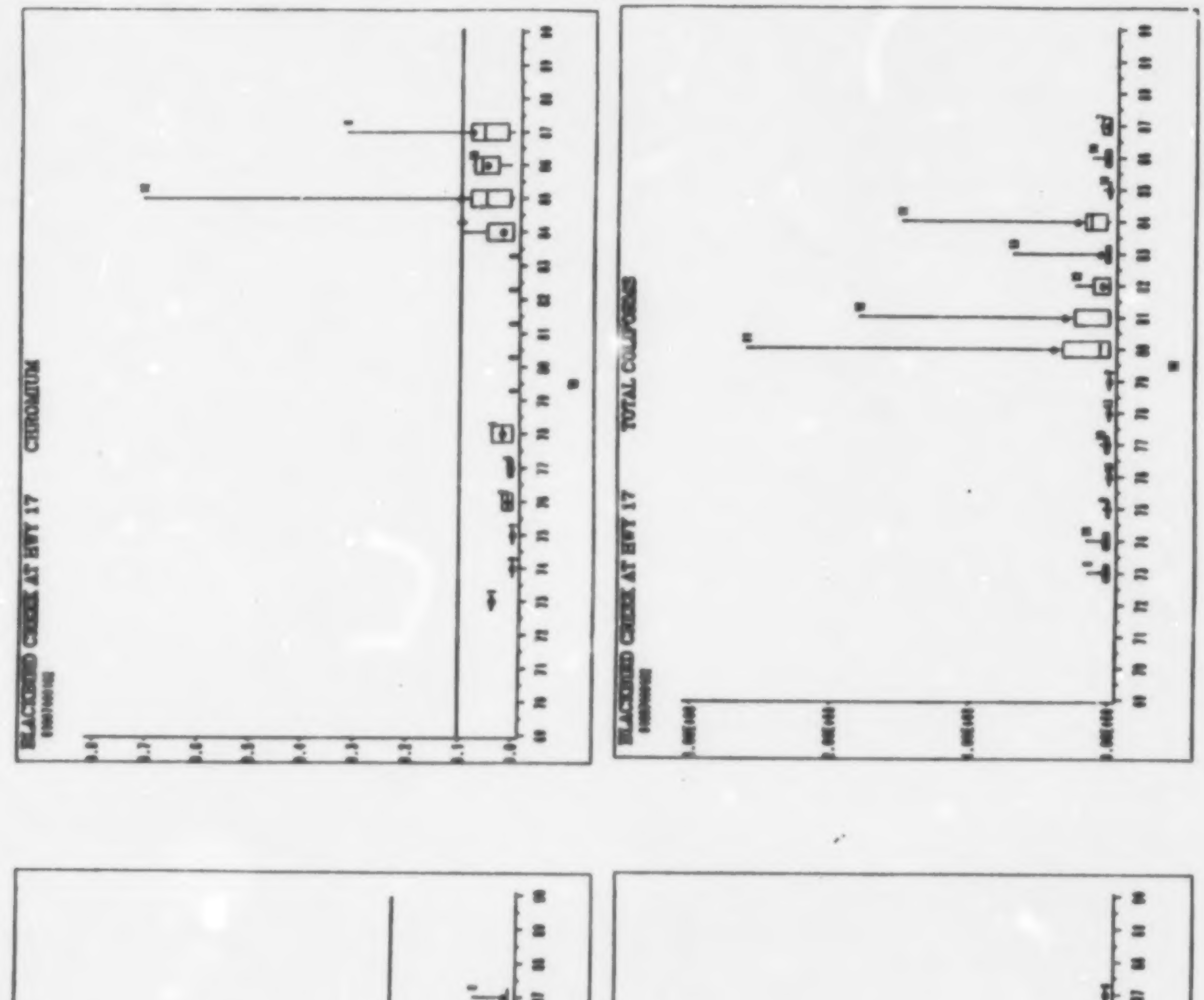

Fig. 33. Water quality in Blackbird Creek.

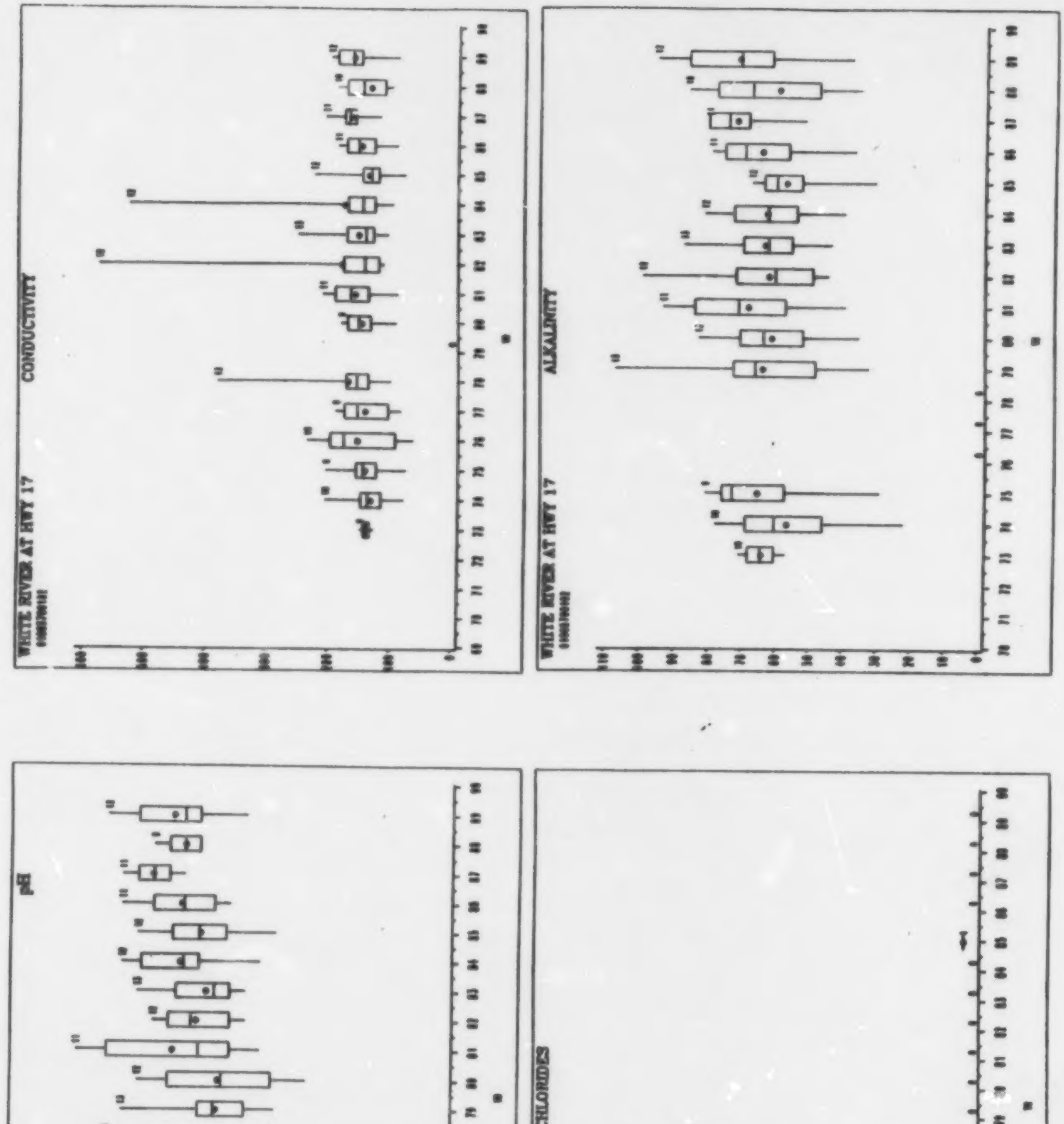

Fig. 34. Water quality in the White River.

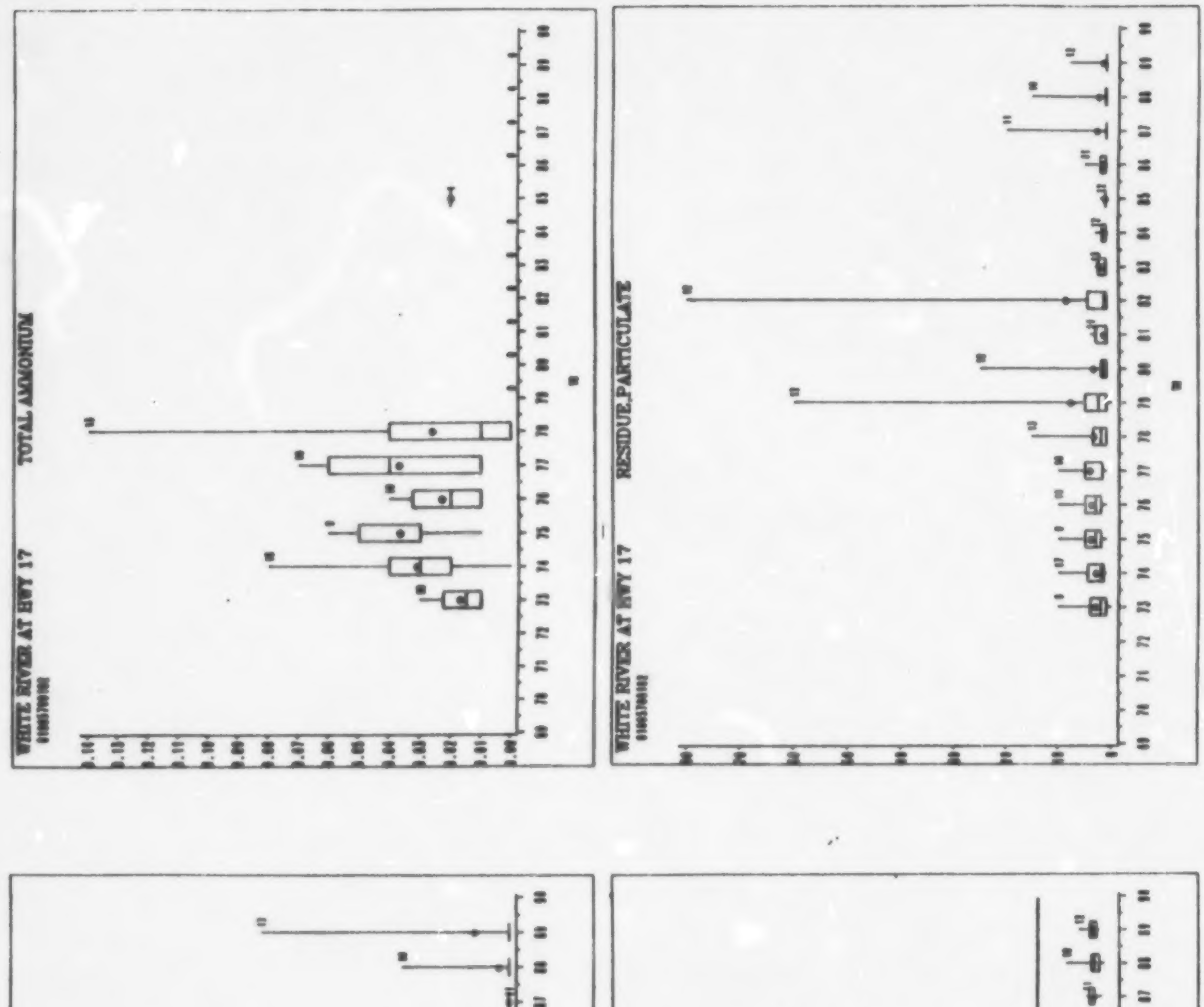

Fig. 35. Water quality in the White River.

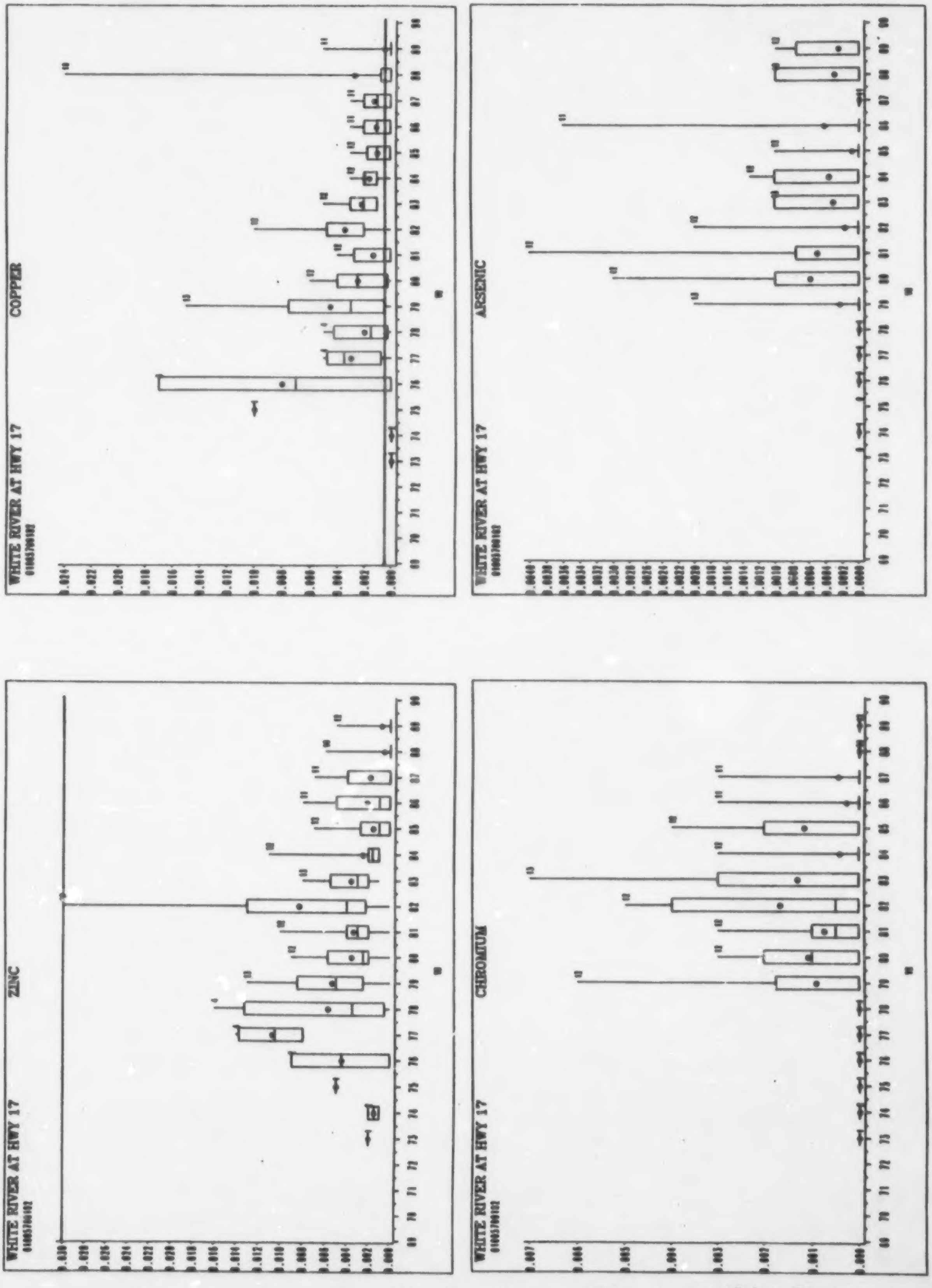

Fig. 36. Water quality in the White River.

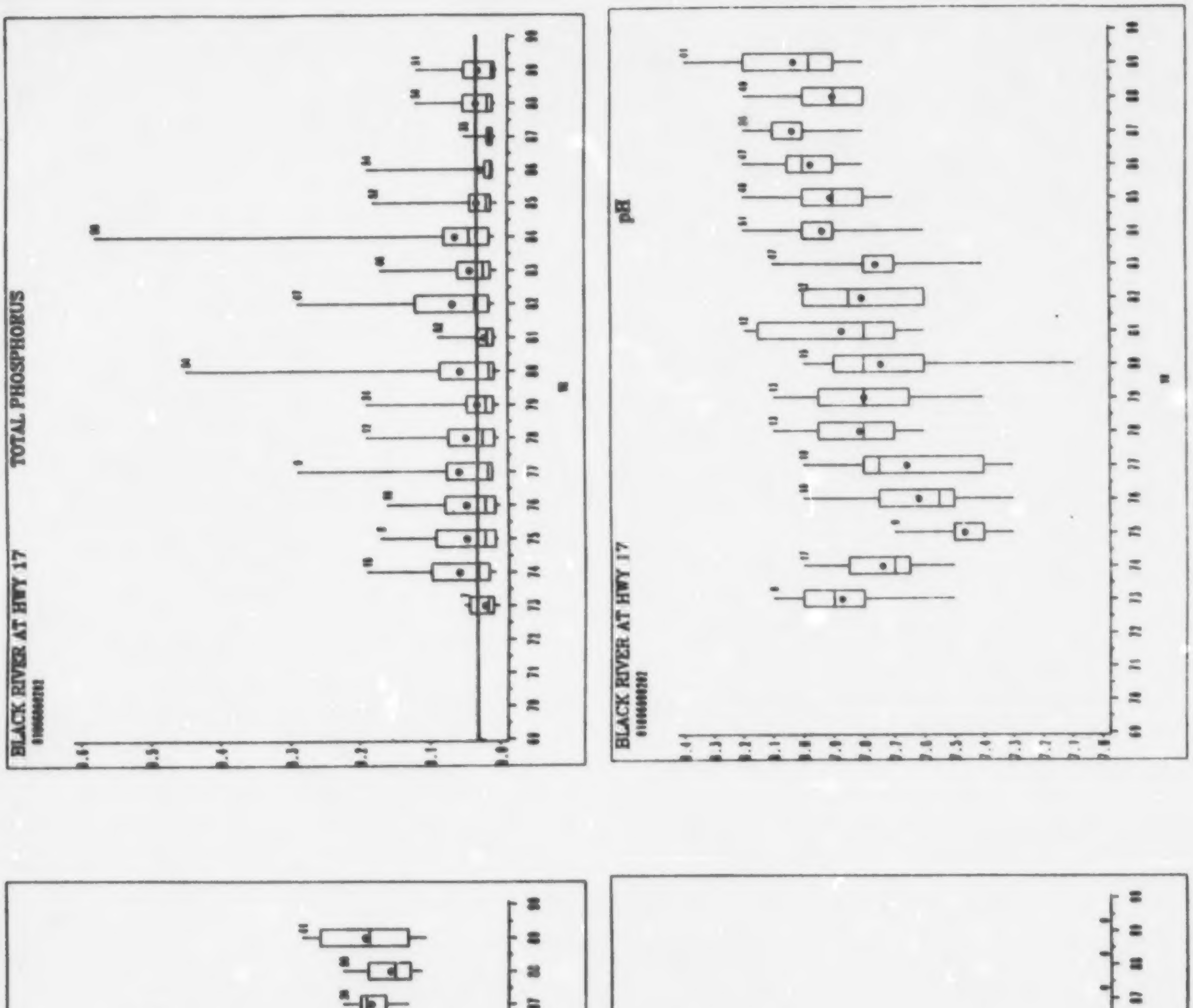

Fig. 37. Water quality in the Black River at Hwy. 17.

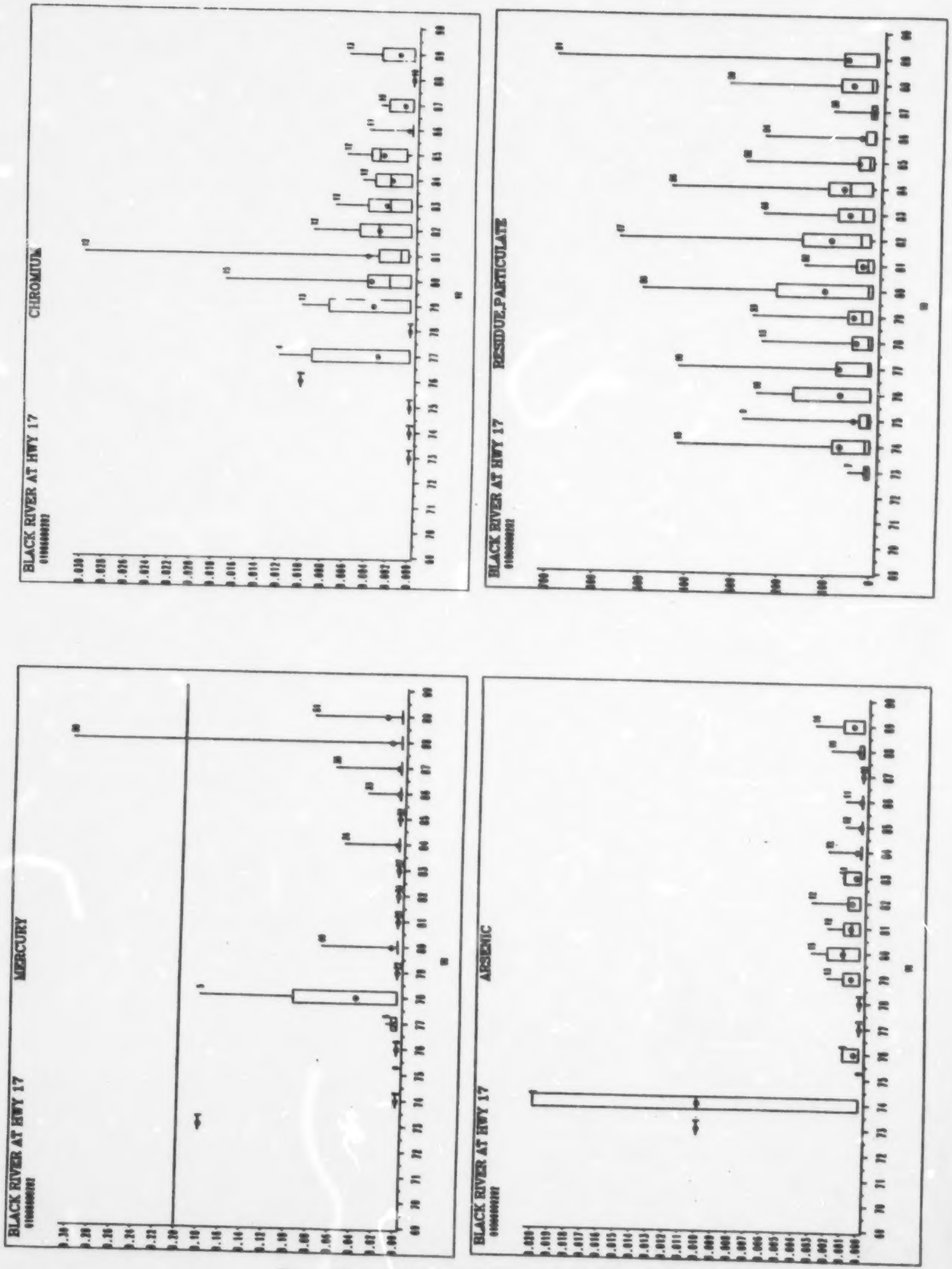

Fig. 38. Water quality in the Black River at Hwy. 17.

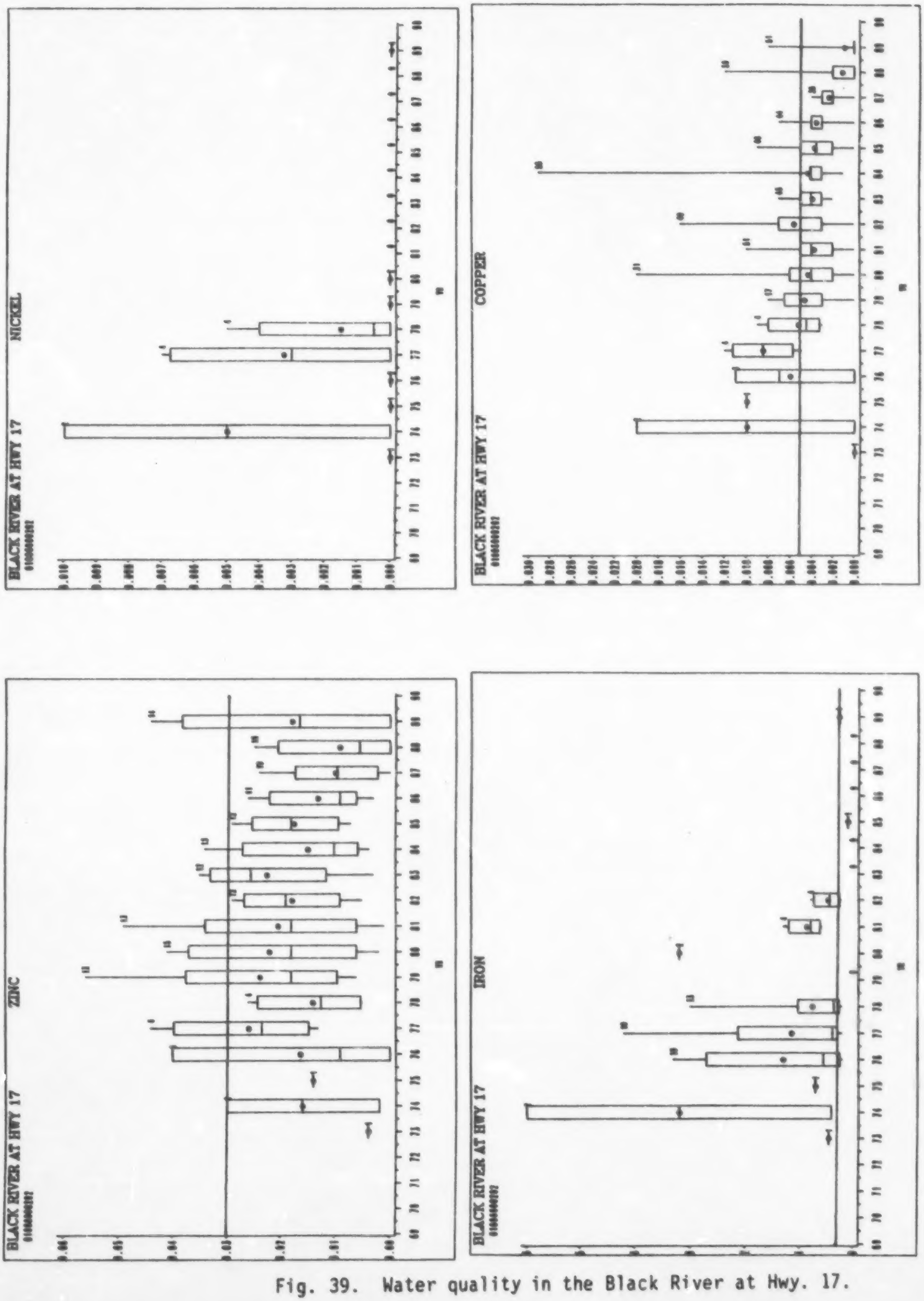

Fig. 39. Water quality in the Black River at Hwy. 17.

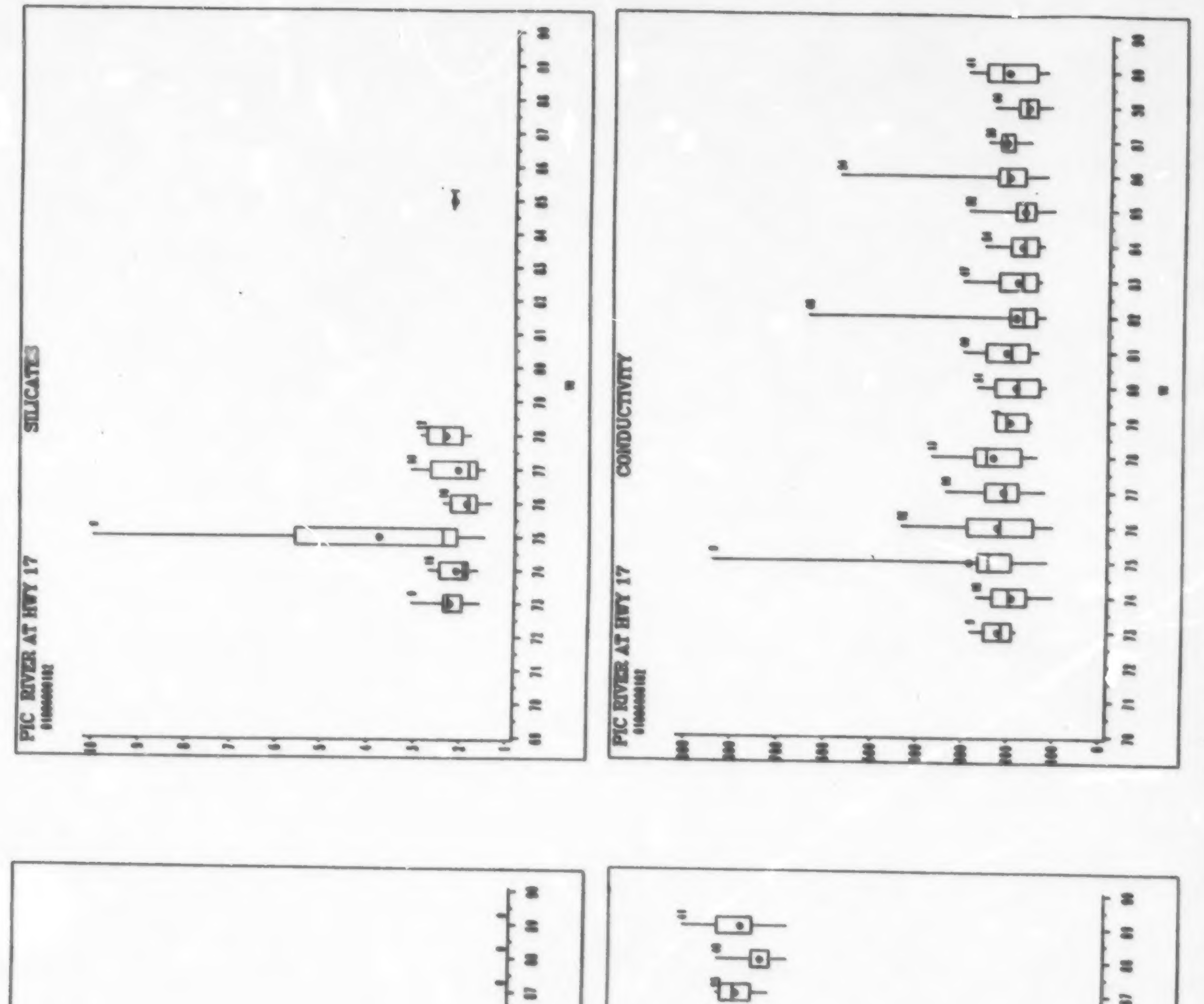

Fig. 40. Water quality in the Pic River.

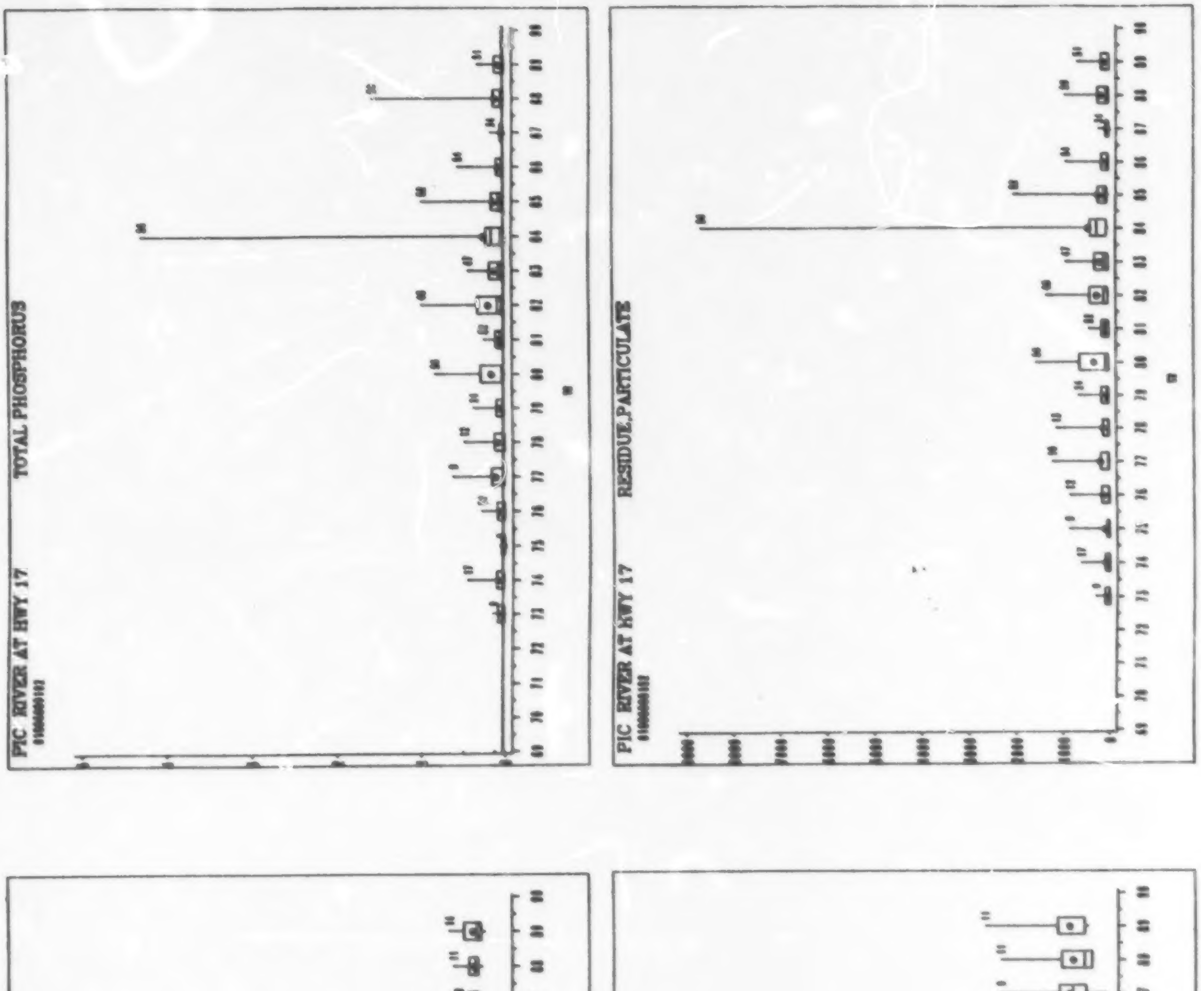

Fig. 41. Water quality in the Pic River.

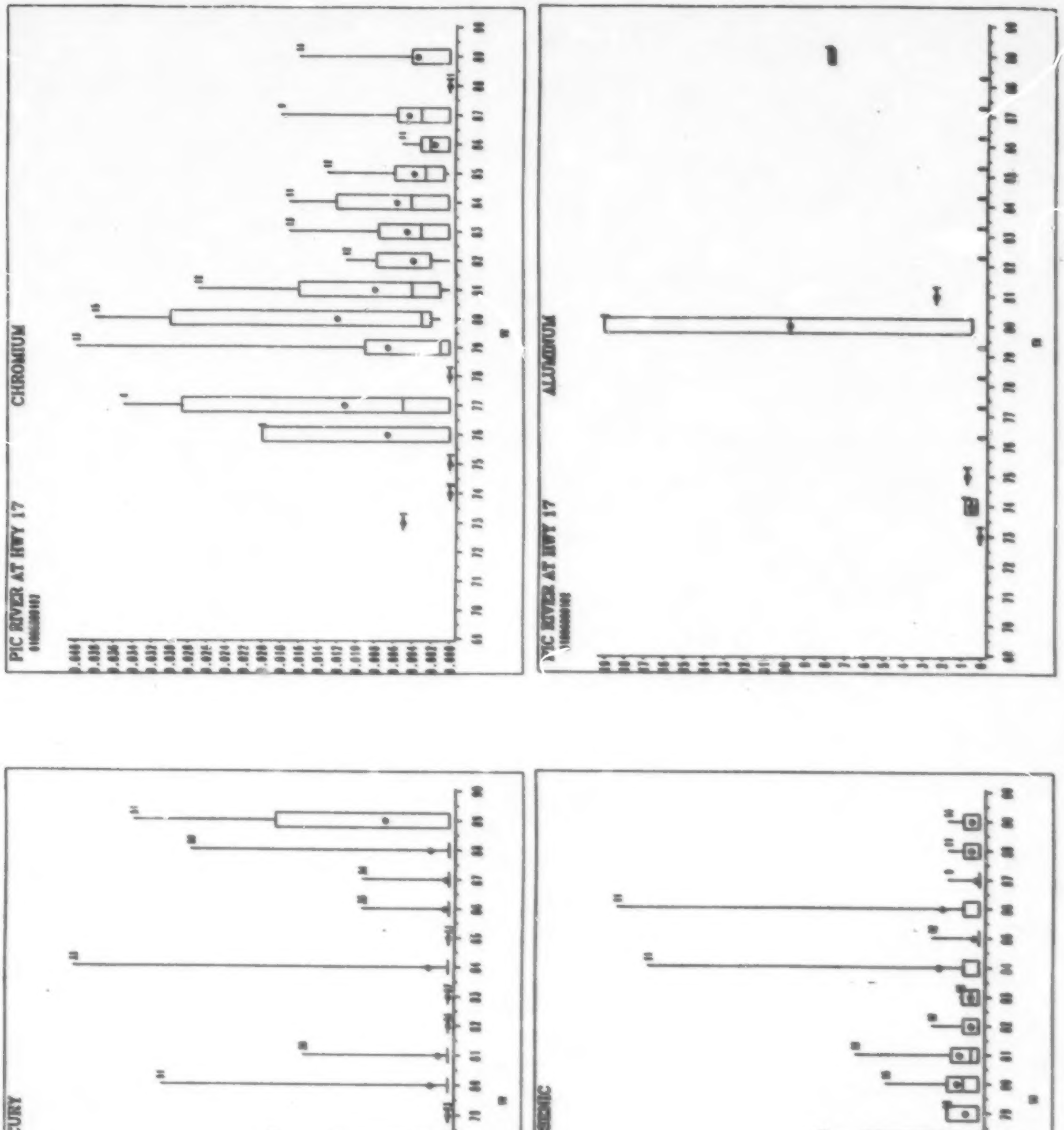

Fig. 42. Water quality in the Pic River.

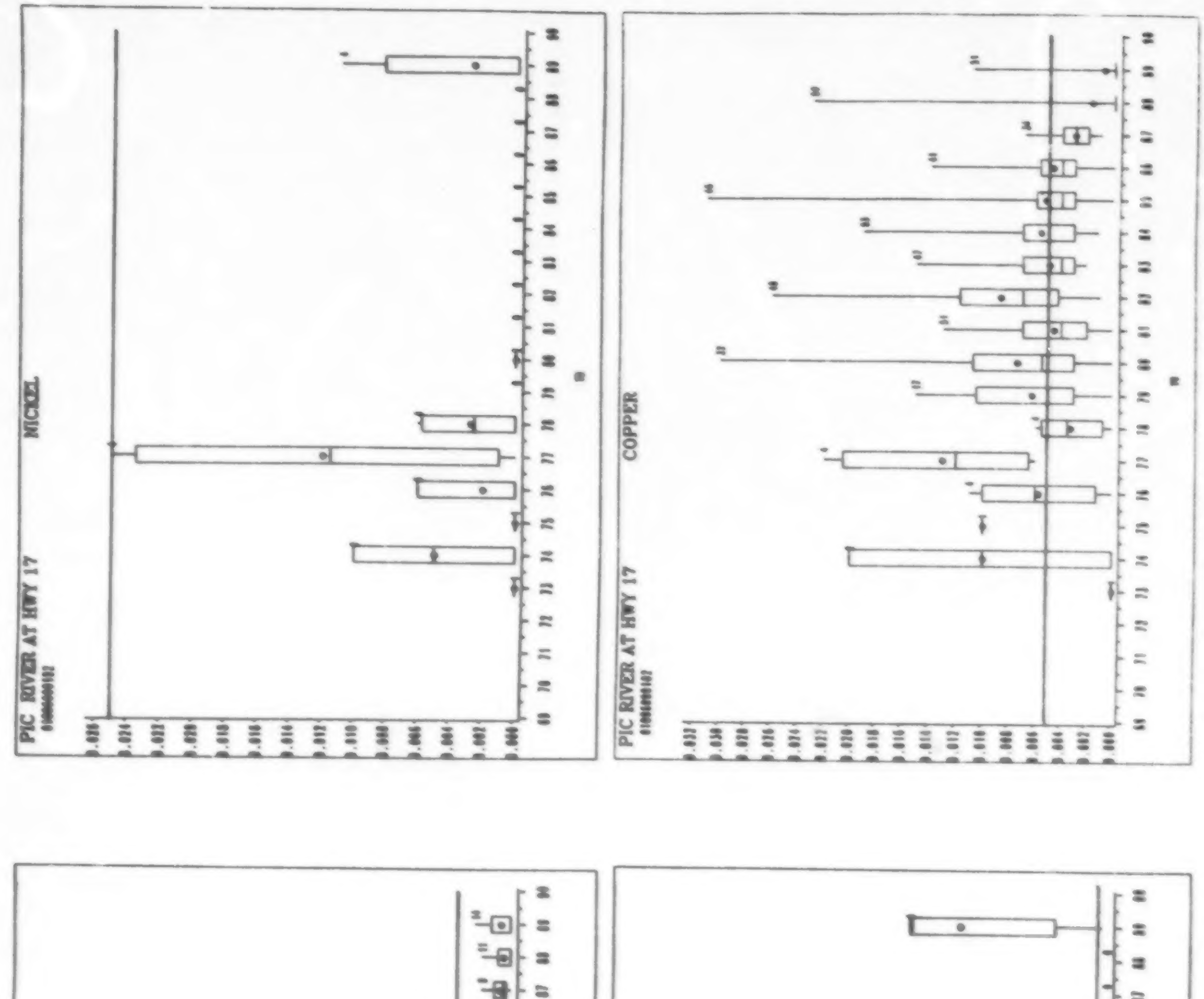

Fig. 43. Water quality in the Pic River.

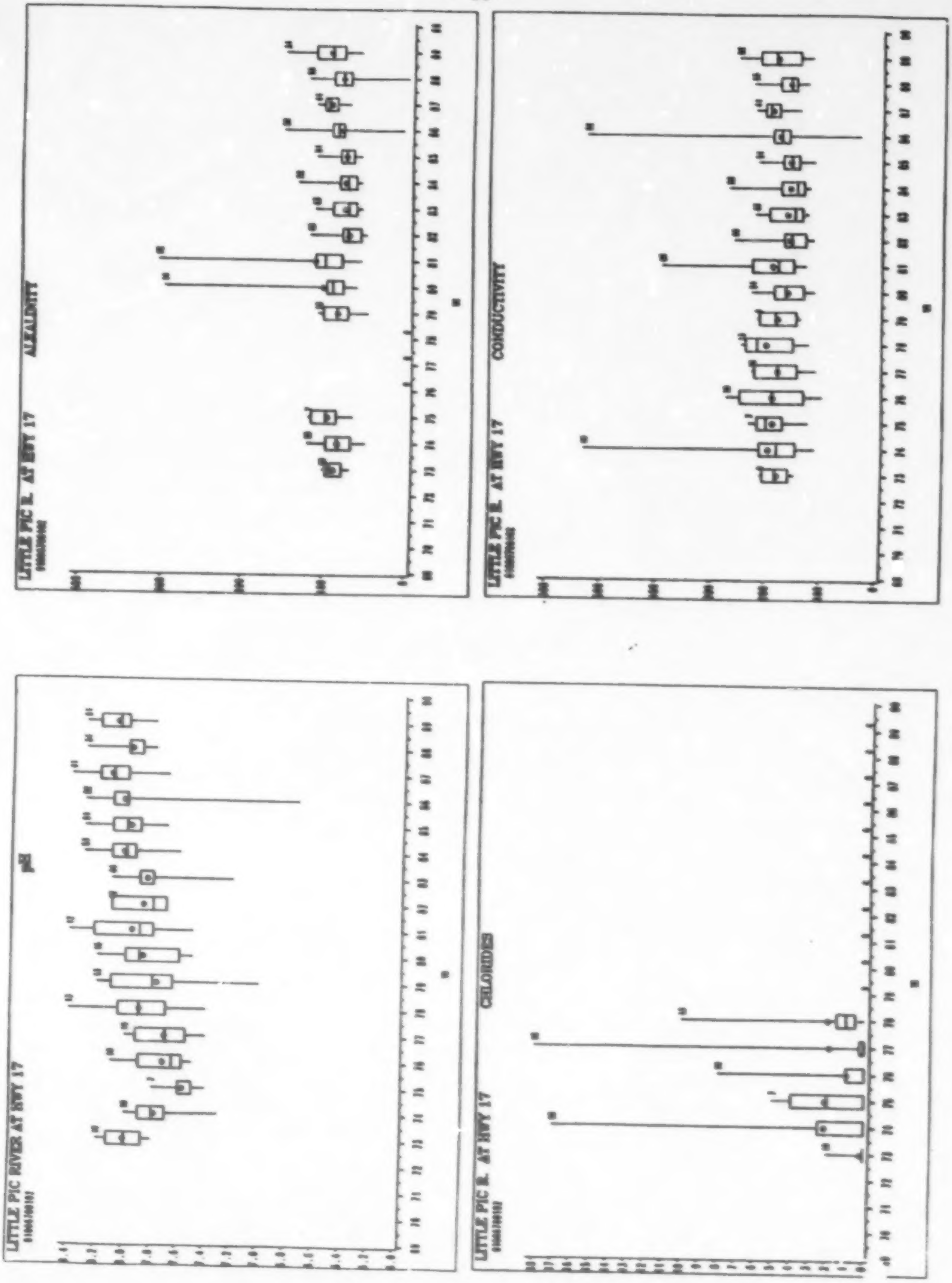

Fig. 44. Water quality in the Little Pic River.

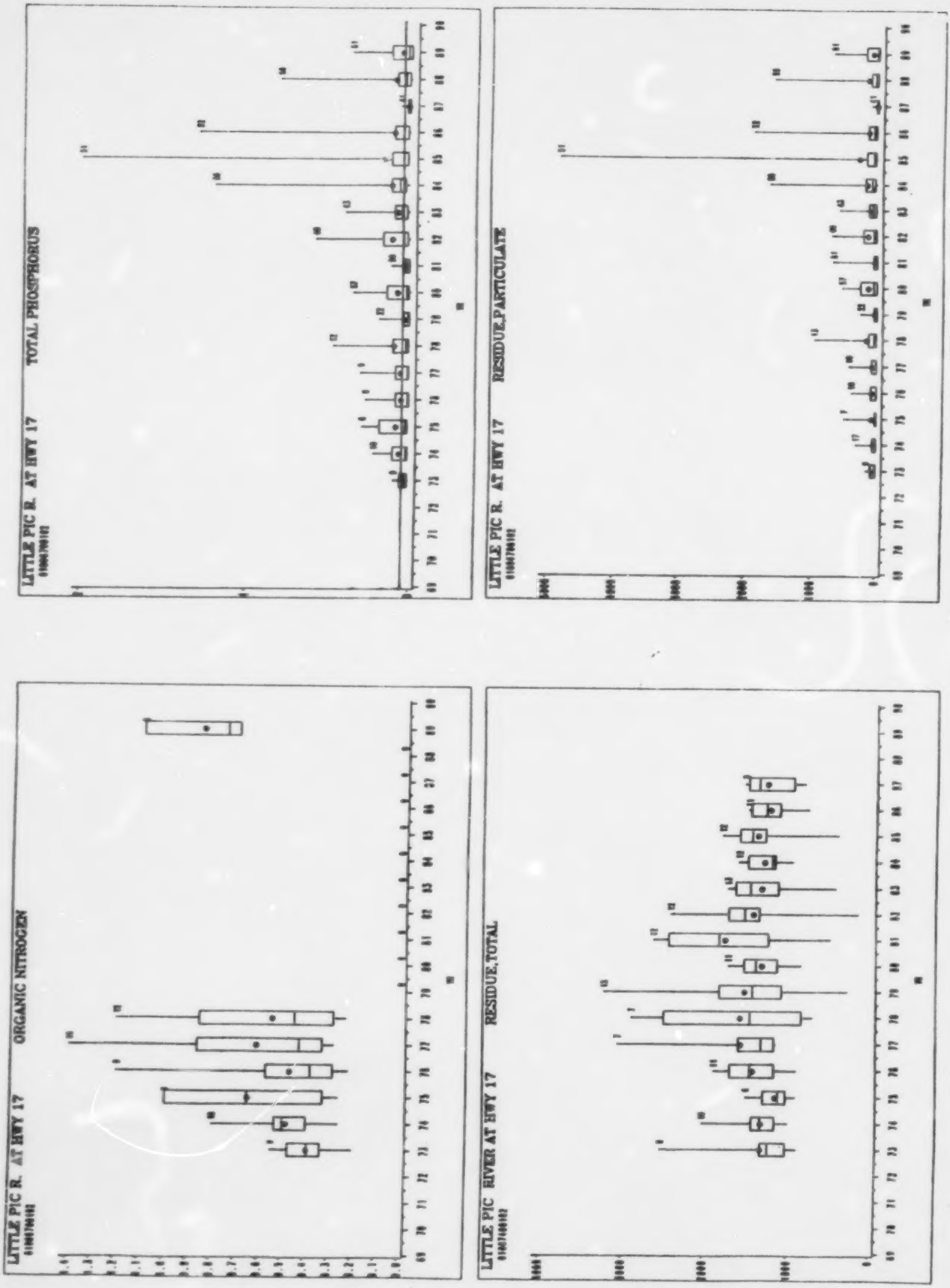

Fig. 45. Water quality in the Little Pic River.

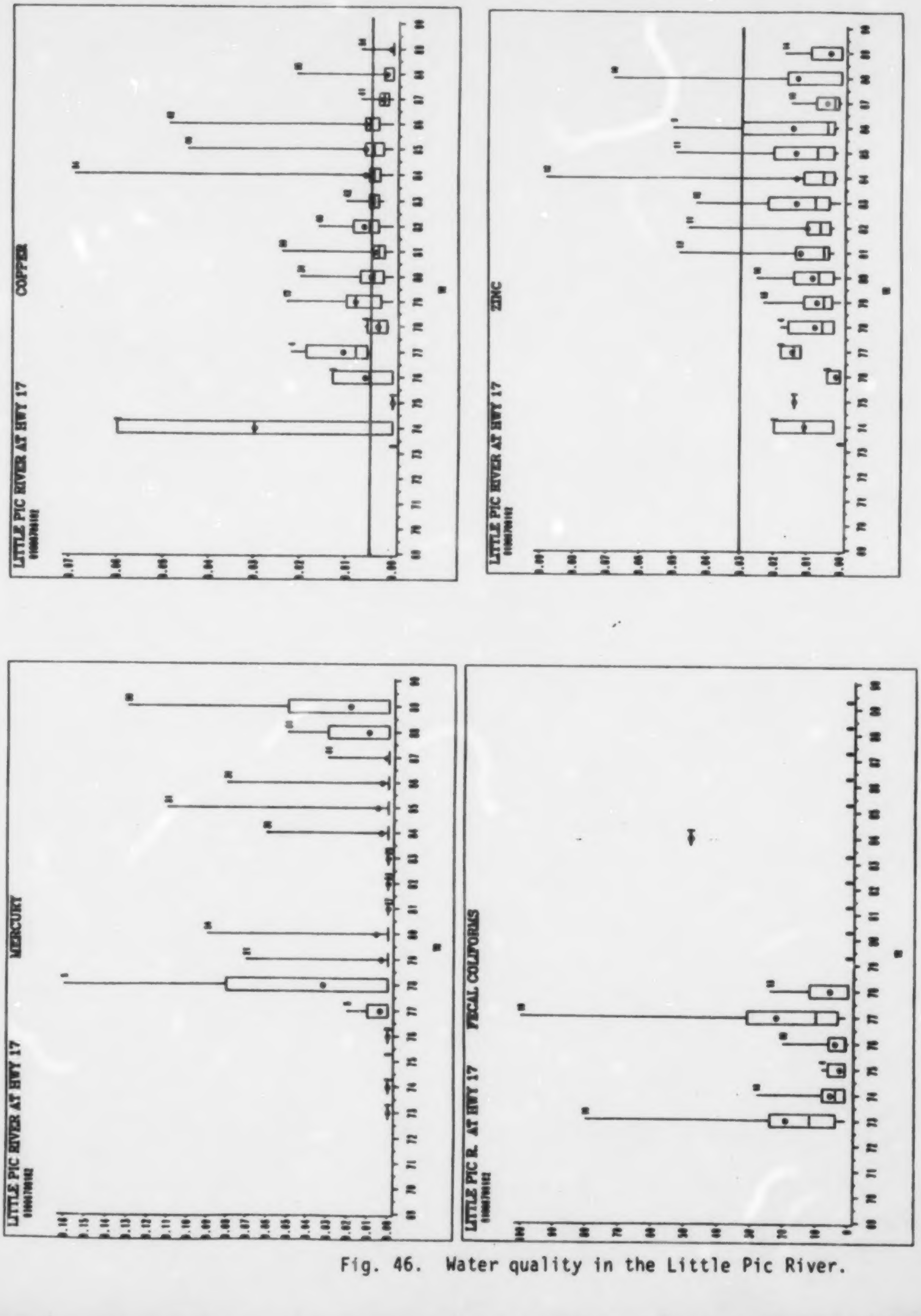

Fig. 46. Water quality in the Little Pic River.

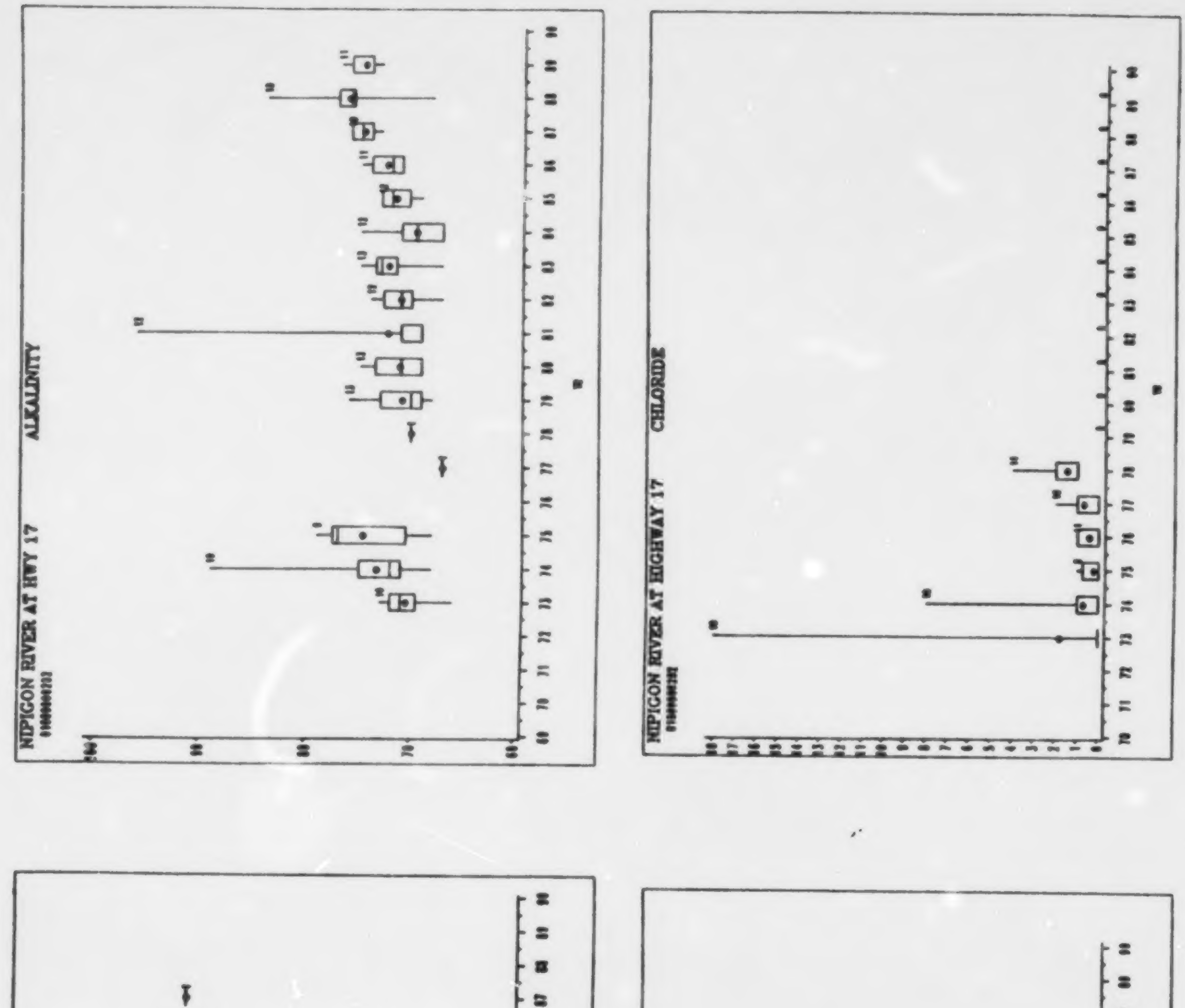

Fig. 47. Water quality in the Nipigon River.

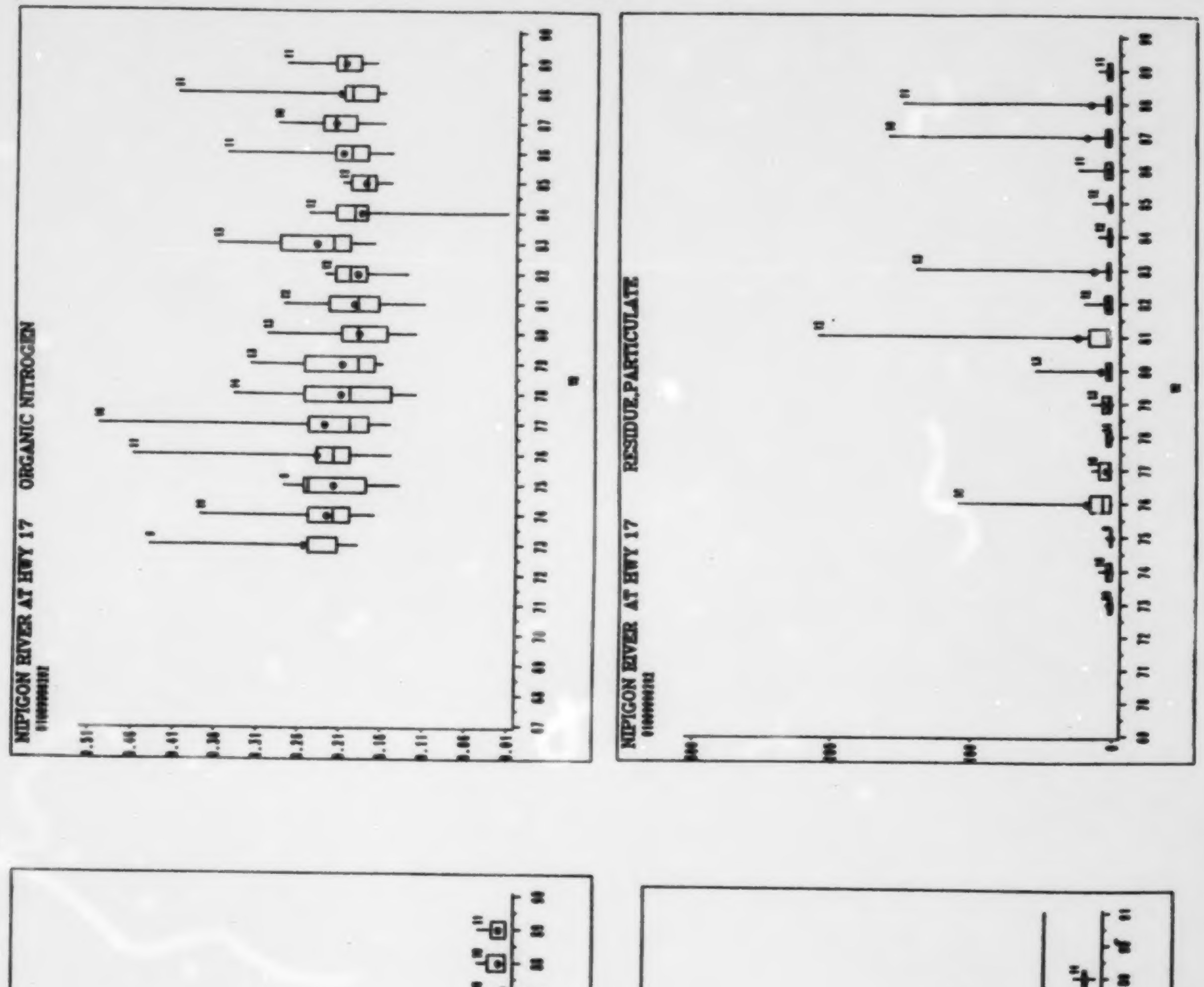

Fig. 48. Water quality in the Nipigon River.

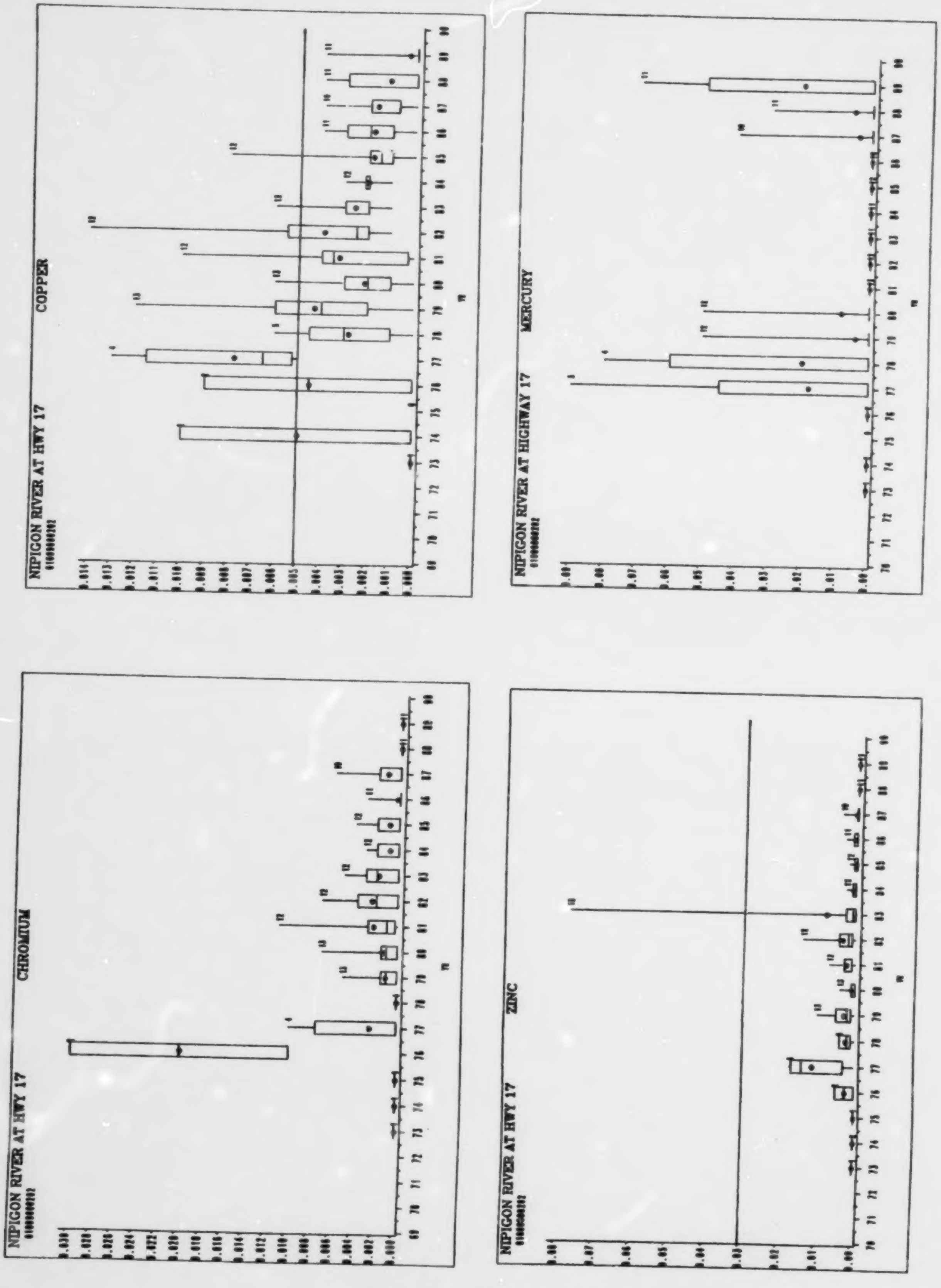

Fig. 49. Water quality in the Nipigon River.

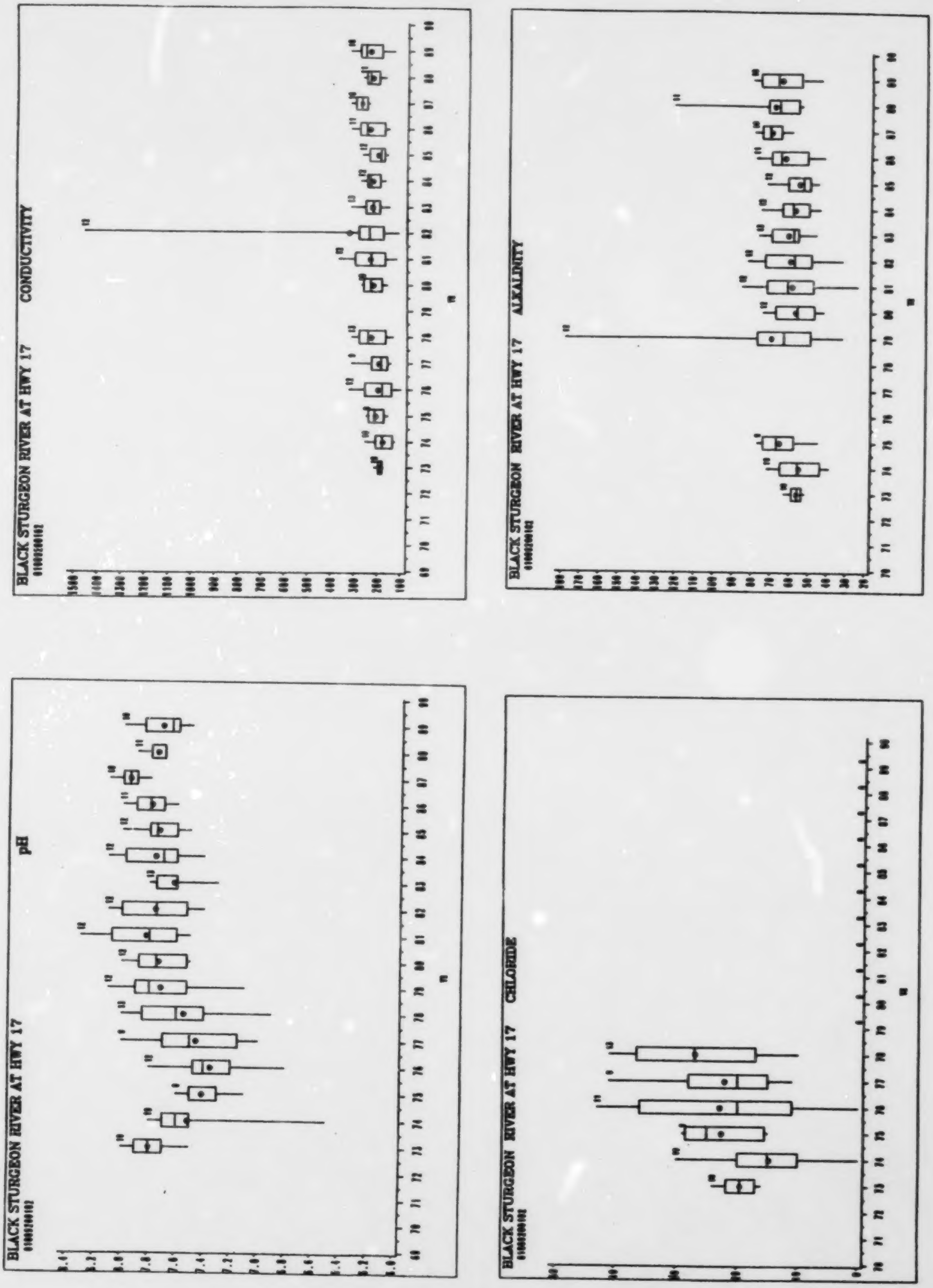

Fig. 50. Water quality in the Black Sturgeon River.

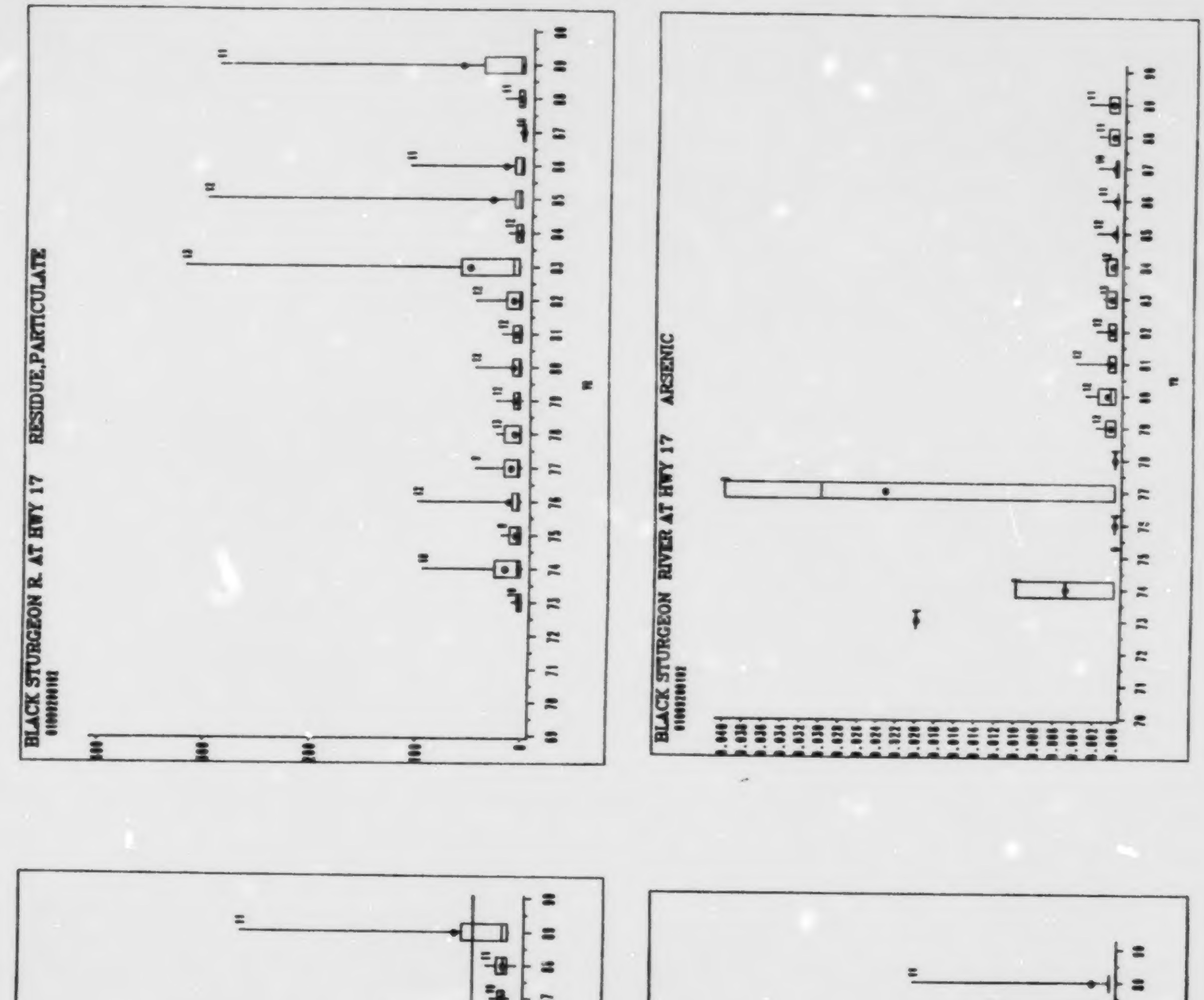

Fig. 51. Water quality in the Black Sturgeon River.

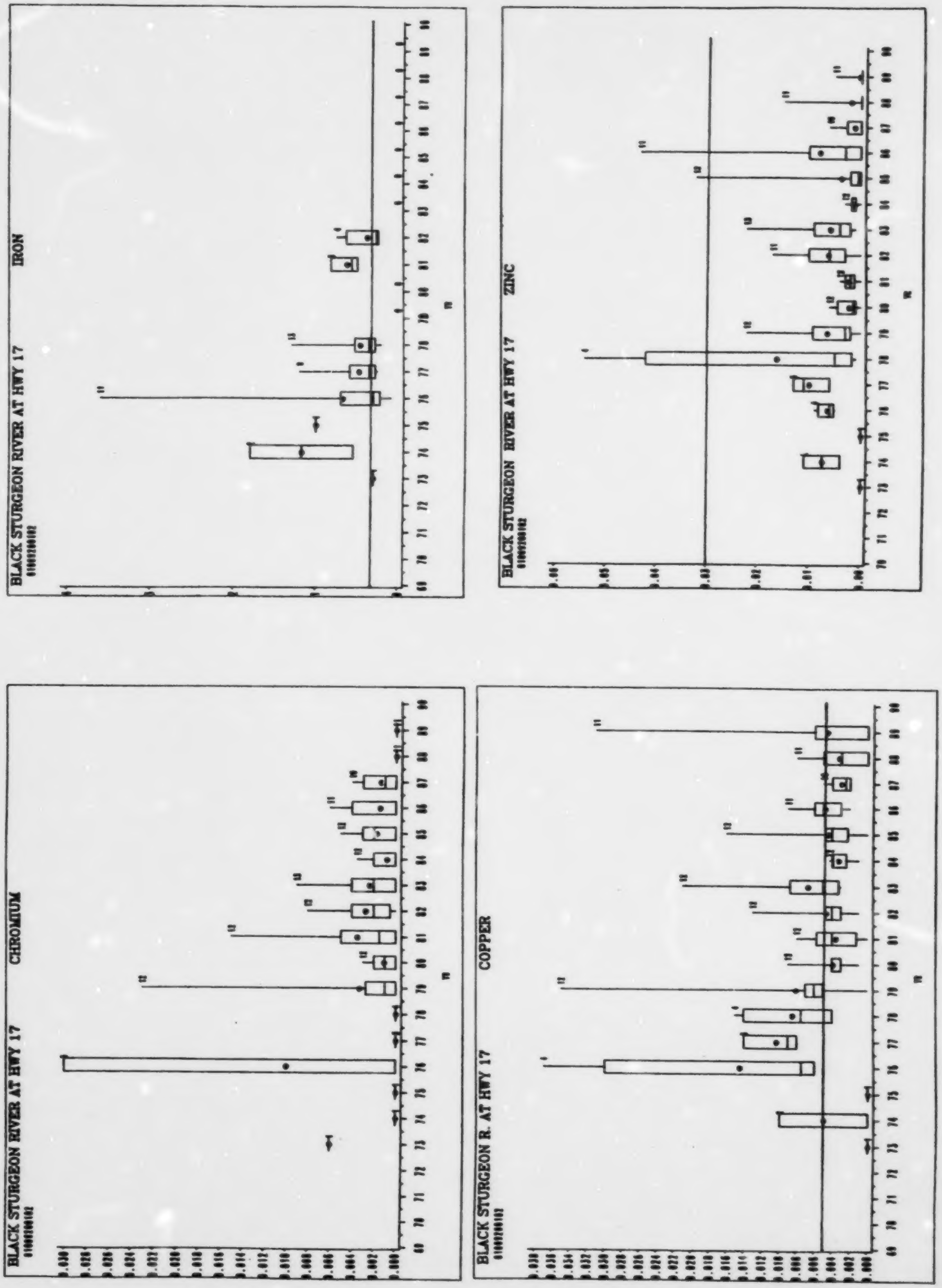

Fig. 52. Water quality in the Black Sturgeon River.

3.2 Summary, City of Thunder Bay: Rivers North of the Kaministiquia River

The Current and McIntyre-Neebing Rivers and McVicar Creek flow through the city and discharge into Thunder Bay harbour. Water quality reflects a variety of sources: light agricultural and urban run-off and, in some cases, limited industrial and municipal inputs.

Bacteria was the contaminant of most significance; levels usually exceeded drinking water guidelines. Phosphorus levels exceed, or have exceeded PWQG's at some stations. However, phosphorus levels have declined, especially since 1985. Conductivity and chlorides increased on most of the rivers in the early 1970's and again in the late 1980's. These may reflect long-term cycles, a phenomenon that also was suggested by data from rivers on the northshore. Levels of most metals also became very low to non-detectable in the late 1980's.

A unique situation is illustrated by the data from the station at Hammond St. on the McIntyre River. The closure in 1978 of a wastewater treatment plant resulted in a dramatic improvement in water quality.

Data for some stations (-0104-001-, 0104-002-, 0105-001 0106-001, 0107-001, -0107-002-) go back as far as 1968. By 1972 conventional parameters were collected almost monthly; metals (excluding mercury) were analyzed several times throughout the year. In 1984, total coliform analysis was discontinued. In 1985 sampling was reduced to the months of May through October at all stations.

3.2.1 Current River

Station code: 01-0104-002-02
Location: at Hwy. 11/17 (Fig. 53). Established 1968
Lat.: 48 29 09.40 **Long.:** 89 11 05.75
UTM: 16 0338550.0 5372400.0

Station type: protection of uses - fisheries, recreation; surveillance - background
Test groups: TBWQ10
Receivers: Lake Superior (Thunder Bay)

Station code: 01-0104-001-02
Location: at Cumberland Street, Thunder Bay (Fig. 53). Established 1968
Lat.: 48 27 19.18 **Long.:** 89 11 10.76
UTM: 16 0338350.0 5369000.0
Station type: protection of uses - fisheries, recreation; surveillance - major tributary mouth
Test groups: TBWQ10
Receivers: Lake Superior (Thunder Bay)

Abatement History

Water quality in the Current River is affected primarily by rural and urban runoff. The upstream station reflects water quality as the river approaches the city of Thunder Bay; the downstream station is below a small hydro-impounded lake (Boulevard Lake) in the city that is used for recreation and is surrounded by parkland.

Water quality, Current River (Figs. 54-59 and Table 5)

Levels of conventional parameters were low in the Current River. Table 5 lists median values for selected parameters, and compares them with median values for other rivers that flow through the city. Metals at the upstream location followed patterns similar to those in the McIntyre River (Section 3.2.3). At the downstream location, zinc levels became more variable in 1986-1987 then were undetectable in 1988 and 1989.

Bacterial data indicate some contamination from human and animal sources. The levels of bacteria indicate that the water was not suitable for drinking. In 1985 through 1987, fecal coliforms occasionally exceeded levels acceptable for swimming (100 counts/100 ml). The only apparent trend was an increase through time in fecal coliforms at Boulevard Lake.

3.2.2 McVicar Creek

Station code: 01-0105-001-02
Location: at Cumberland Street, Thunder Bay (Fig. 60-61). Established 1968
Lat.: 48 26 23.78 **Long.:** 89 12 53.04
UTM: 16 0336200.0 5367350.0
Station type: diffuse sources - urban land; surveillance - major tributary mouth
Test groups: TBWQ10
Receivers: Lake Superior (Thunder Bay)

Abatement History

Water quality in McVicar Creek is affected primarily by residential urban runoff. Some light industry that discharges to municipal sewers also is located along its banks.

Water quality, McVicar Creek (Figs. 60-61 and Table 5)

Water quality in McVicar Creek was similar to that in the Neebing and McIntyre Rivers. Alkalinity, chlorides, and conductivity were moderately higher for these waters than for the Current River, with gradual increases occurring over time, especially since 1985. Since 1985, there has been a reduction in suspended solids, organic nitrogen, total phosphorus and fecal coliform levels.

3.2.3 McIntyre River

Station code: 01-0106-002-02
Location: at Hwy. 11/17, Thunder Bay (Fig. 63-64). Established 1972
Lat.: 48 23 59.74 **Long.:** 89 14 53.25
UTM: 16 333600 5362975
Station type: protection of use - fisheries, recreation; surveillance - background

Test groups: TBWQ10
Receivers: Lake Superior (Thunder Bay)

Station code: 01-0106-001-02
Location: at Hammond Avenue, Thunder Bay (Fig. 65-68). Established 1968, discontinued 1984.
Lat.: 48 24 34.10 **Long.:** 89 13 53.95
UTM: 16 334850 5364000
Station type: point source - waste water treatment plant; diffuse sources - urban land; surveillance - monitoring, International Joint Commission
Test groups: TBWQ10
Receivers: Lake Superior (Thunder Bay)

Abatement History

Water quality in the McIntyre River is affected primarily by runoff from rural and residential areas. The Port Arthur WWTP discharged into the McIntyre River above Hammond Avenue until 1978. Sewage from Port Arthur was diverted to the WWTP at the mouth of the Kaministiquia River after 1978. In 1983 the lower sections of the McIntyre and Neebing Rivers were diverted into a common channel, just south of the mouth of the Neebing River, called the Neebing-McIntyre Diversion.

Water quality, McIntyre River (Figs. 62-68 and Table 5)

At the station on the outskirts of the city (-0106-002-) the McIntyre River had levels for conventional parameters that lie between those for the Current River and other rivers and creeks listed on Table 5. Increases occurred in conductivity and chloride levels between 1972 and 1976, and again since 1985. Levels of cadmium and lead occasionally exceeded PWQO's in the early 1980's, then declined; median values were below the limits of detection. Zinc also declined after 1982, was undetected in 1987, then was detected again in 1988 and 1989. This was the only location in Thunder Bay (other than on the Kaministiquia River) reporting detectable zinc in 1988 and 1989.

Below Wastewater Pollution Plant (WWTP)

The figures for Station -01060-001-, at Hammond Ave. provide a graphical picture of the effect of eliminating a point source from a river. A comparison of data for the 1973 to 1978 period with more recent information (1978 onward) show which parameters most influenced by the WWTP effluent.

Dramatic declines occurred after 1978 in BOD_5, nutrients (total phosphorus, ammonia, organic nitrogen), and total and fecal coliforms. pH showed fewer extreme lows. Conductivity, and solids (dissolved and suspended) declined slightly. Chlorides had increased between 1974 and 1976 and, after 1978, dropped to pre-1974 levels.

Copper levels decreased through 1981 and became less variable but were higher in 1982-83. Chromium levels increased over the period of 1979 -1983 from below detection to a median of 0.009 mg/ℓ. This suggests that prior to 1979, chromium may have been removed in primary treatment. Several metals consistently exceeded PWQO's: cadmium (after 1975), copper and iron. Lead exceeded the PWQO of .005 mg/ℓ in 1976-78 and 1982. Zinc was in exceedance in the late 1970's, was lower in 1980 and 1981, then rose again in 1982-83. Figures 67 and 68 show the range of patterns and values recorded for other metals.

3.2.4 Neebing River

Station code: 01-0107-002-02
Location: at Hwy. 11/17 West of Mapleward Side Road (Fig. 69-70). Established 1968, discontinued 1984.
Lat.: 48 22 54.32 **Long.:** 89 21 29.07
UTM: 16 325400 5361200
Station type: protection of uses - fisheries, recreation; surveillance - background
Test groups: TBWQ10
Receivers: Lake Superior (Thunder Bay)

Station code: 01-0107-001-02
Location: at 110 Avenue, Thunder Bay (Fig. 71-72).
Established 1972
Lat.: 48 24 04.86 **Long.:** 89 14 40.10
UTM: 16 333875 5363125
Station type: diffuse sources - urban; surveillance -monitoring
Test groups: TBWQ10
Receivers: Lake Superior (Thunder Bay)

Abatement History

Water quality in the Neebing River is affected mainly by rural and residential runoff. In 1983 the lower sections of the McIntyre and Neebing Rivers were diverted into a common channel just south of the mouth of the Neebing River, called the Neebing-McIntyre Diversion.

3.2.5 Neebing-McIntyre Diversion

Station code: 01-0107-003-02
Location: at 110 Avenue, Thunder Bay (Fig. 73-74). Established 1983
Lat.: 43 23 46.07 **Long.:** 89 13 25.10
UTM: 335400 5362500
Station type: diffuse sources - urban land; protection of use - protection; surveillance - major tributary mouth
Test groups: TBWQ10
Receivers: Lake Superior (Thunder Bay)

Abatement History

This station was established to monitor water quality on the diversion channel, constructed in 1983, which receives flow from the Neebing and McIntyre Rivers. There are only six years of data at this station.

Water quality, Neebing River (Figs. 69-74 and Table 5)

Conventional Parameters

Alkalinity at stations -0107-001- and -0107-002- was elevated relative to other rivers within the boundaries of Thunder Bay (see Table 5). It was highly variable within any one year, e.g. from 40 to 130 mg/ℓ, and highly variable from year to year, e.g. from median lows of 60 to highs of 125 mg/ℓ. There was less year-to-year variability in alkalinity at the diversion than at other stations. Between 1985 and 1986 the median value at the upstream station (-0107-002-) rose from 90 to 125 mg/ℓ while median values at the diversion (-0107-003-) increased from 85 to 95 mg/ℓ.

The pattern for conductivity, chlorides and pH was similar to other rivers. There was a gradual increase through time, with fluctuations that may reflect multi-year cycles (especially conductivity) or steps (chlorides and pH).

Nutrient levels were higher at downstream stations than upstream or on other rivers. Total phosphorus increased from less than 0.02 mg/ℓ (based on medians estimated from the figure for the periods 1968-1982 and 1983-1989) for the upstream station to 0.040 mg/ℓ at the old downstream station (-0107-001-) and 0.025 mg/ℓ in the new diversion channel. Organic nitrogen levels were relatively high; median values ranging from .55 to .90 mg/ℓ for the three stations. The year-to-year variability of both nutrients suggests a cyclical pattern; within year variability was less in the 1980's than in the 1970's.

Fecal coliform levels were elevated. Median values ranged between 24 and 116 counts/100 ml while maximum values for fecal coliforms at the three stations (highway 11/17, 110th Avenue and the diversion) were 1930, 16,000 and 800 counts/100 ml respectively.

3.3 Summary, Lower Kaministiquia River

The Kaministiquia River is the largest single river flowing into Thunder Bay. Near its mouth a delta is formed, creating three main channels, the Kaministiquia, the McKellar and the Mission Rivers. Several major industrial and municipal dischargers are located on the lower river. As a result of these discharges, the lower Kaministiquia River is the most severely polluted of any of the rivers that flow through the city of Thunder Bay. Detailed studies have been conducted on the water and sediment quality in the area, most recently by Boyd (1990). The current report tracks conventional parameters, bacteria and metals at eight monitoring stations: three above the delta, one at the first junction (with the Mission River), one near the junction of the McKellar River and one at each of the three channel mouths.

The conventional parameters of primary concern are those associated with oxygen depletion in the river. BOD_5 and suspended solids were high within the Kaministiquia River from the pulp mill to the confluence of the Mission River and at the mouth of the Mission River. Downstream, BOD_5 and suspended solids declined in the Kaministiquia and McKellar Rivers. Several other parameters show a similar pattern. BOD_5, chlorides and conductivity fluctuated over the years, reflecting the combined effects of at least two factors: improvements in the quality of various effluents, and flow rates within the river. Water levels in Lake Superior and lake currents (seiches) also may influence the extent to which contaminants are flushed from the river mouths.

Nutrients (phosphorus and nitrogen) were high, with median values increasing at the mouth of the Kaministiquia River (total phosphorus median value of .056 mg/ℓ).

Bacterial levels were very high along the river; levels of total coliforms usually were greater than 160,000 counts/100 ml. There are insufficient data to distinguish between bacterial species found in wood fibre and those commonly associated with animal and human waste.

Some metals tended to be high at the station upstream of industrial activity; aluminum, cadmium, copper, iron and zinc commonly exceeded PWQO's. High background levels are thought to be the result of non-point sources, including weathering and atmospheric transport.

Mercury is monitored only at one station, just below the pulp and paper mill discharge. The single most important point source was eliminated in 1974, when the chlor-alkali plant that introduced mercury into the river was decommissioned. Mercury was undetectable in most samples throughout the 1980's, but was detected in more samples and at higher levels in 1989.

Median values of other metals increase by no more than a factor of two at downstream locations. The pattern is different for each metal and each location. Metals seem to have been particularly erratic in 1988 and 1989. They were higher than usual in some locations, undetectable in others. Only some of these metals can be traced to specific industrial activities.

Station code: 01-0108-002-02
Location: Upstream of Hwy. 61 bridge (Fig. 75-78). Established 1966
Lat.: 43 23 46.07 **Long.:** 89 13 25.10
UTM: 329200 5357075
Station type: protection of uses - fisheries, recreation; surveillance - background
Test groups: TBWQM3 TBCM4 ALUT
Receivers: Lake Superior (Thunder Bay)

Station code: 01-0108-003-02
Location: Middle of Turning Basin (Fig. 79-80). Established 1968
Lat.: 48 20 44.03 **Long.:** 89 18 05.06
UTM: 329475 5357050
Station type: point sources - industrial
Test groups: TBWQM3 ALUT
Receivers: Lake Superior (Thunder Bay)

Station code: 01-0108-001-02
Location: At Hwy. 61B Bridge (Fig. 81-85). Established 1966
Lat.: 48 21 32.00 **Long.:** 89 17 14.98
UTM: 330550 5358500
Station type: point sources - industrial; surveillance - International Joint Commission
Test groups: TBWQM3 TBCM4 ALUT
Receivers: Lake Superior (Thunder Bay)

Station code: 01-0108-005-02
Location: At Mission River Junction (Fig. 86-90). Established 1968
Lat.: 48 22 07.81 **Long.:** 89 15 02.90
UTM: 333300 5359525
Station type: point sources - industrial
Test groups: TBWQM3 TBCM4 ALUT
Receivers: Lake Superior (Thunder Bay)

Station code: 01-0108-004-02
Location: Near Kaministiquia River Mouth (Fig. 91-94). Established 1978
Lat.: 48 23 33.45 **Long.:** 89 13 07.53
UTM: 335750 5362100
Station type: point sources - sewage treatment plant, industrial; surveillance - major tributary mouth
Test groups: TBWQM3 TBCM4 ALUT
Receivers: Lake Superior (Thunder Bay)

Station code: 01-0109-001-02
Location: McKellar River at 104th Avenue (Fig. 95-98). Established 1966
Lat.: 48 22 37.69 **Long.:** 89 14 25.32
UTM: 334100 5390425
Station type: point sources - industrial
Test groups: TBWQM3 TBCM4 ALUT
Receivers: Lake Superior (Thunder Bay)

Station code: 01-0109-002-02
Location: Near McKellar River Mouth (Fig. 99-102). Established 1968
Lat.: 48 22 38.68 **Long.:** 89 13 34.32
UTM: 335150 5360425
Station type: point sources - industrial; surveillance -major tributary mouth
Test groups: TBWQM3 TBCM4 ALUT
Receivers: Lake Superior (Thunder Bay)

Station code: 01-0110-001-02
Location: Near Mission River Mouth (Fig. 103-106). Established 1968
Lat.: 48 21 32.96 **Long.:** 89 13 41.17
UTM: 334950 5358400
Station type: point sources - industrial; surveillance -major tributary mouth
Test groups: TBWQM3 TBCM4 ALUT
Receivers: Lake Superior (Thunder Bay)

Abatement History

Canadian Pacific Forest Products (formerly Great Lakes Forest Products Ltd.)

Canadian Pacific Forest Products is located in the City of Thunder Bay on the north bank of the Kaministiquia River and has been in operation since late 1930's (formerly Great Lakes Forest Products). Final effluent is discharged into the Kaministiquia River approximately 1 km downstream of Highway 61. Over its relatively long history of operation many changes in the mill complex have occurred. Highlights of these changes are summarized below.

In the second quarter of 1975, the sulphite pulping process, a part of the newsprint mill, was changed from a low-yield magnesium-base process to a high-yield magnesium base process. In 1976, the sulphite pulping process was converted to a high-yield sodium-base system. This change had little effect on the effluent, but facilitated future cross-recovery of the spent sulphite liquor in the kraft recovery furnace.

During the period from January 1973 to December 1982, the most significant change affecting effluent quality was the installation of a closed-circuit kraft mill, completed in 1976. At the time of construction this system offered several advantages. It was anticipated that BOD_5, colour, and suspended solids would be greatly reduced. In addition, these changes were to eliminate 50% of the chlorinated organic compounds, reduce foaming and lower energy consumption. This process was discontinued in 1982 as the full benefits anticipated were not realized.

With start-up of this kraft mill in 1976, total production increased by 30%, with little or no change in the total discharge of BOD_5 and suspended solids. In the years from 1978 to 1982, with improvements to the closed-cycle process in the "B" mill, through cross-links with the "A" mill, and a coordinated BOD_5 reduction program, the total BOD_5 from the mill complex was reduced by approximately 20%. Suspended solids remained essentially constant over this period.

In 1989 the mill complex consisted of a stone groundwood, sodium-based high-yield sulphite mill, and two conventional kraft mills (the "A" and "B" mills), a stud lumber mill and a wafer/particle board mill. Hardwood and softwood trees were used in the production of approximately 400,00 tons/year of bleached and unbleached kraft pulp, 400,00 tons/year newsprint, 130,000,000 tons/year waferboard and 115,000,000 board feet/year of stud lumber. The volume of effluent discharged was approximately 180,000 m^3/day.

In 1989, Canadian Forest Products announced that a UNOX modular, high-rate secondary treatment system would be installed and operational by 1991. This system is designed to reduce BOD_5 and suspended solids. A reduction in chlorinated organics was also expected from the implementation of secondary treatment. Final effluent usually exceeds provincial toxicity standards, however, it is anticipated that the effluent will not be acutely lethal to test fish after full implementation of secondary treatment.

In 1991, the sodium-based high-yield sulphite mill was replaced by a new thermo-mechanical pulping complex. Both the stud mill and the wafer/particle board complex are no longer operational.

All domestic sewage generated at the mill is collected and treated either in the septic tanks with tile fields or rotating biological contactors. Effluents are chlorinated prior to discharge into the Kaministiquia River.

Reichhold Chemicals Limited

In 1976 Reichhold Chemicals, located on the Kaministiquia River at the Turning Basin, started producing urea-formaldehyde resins for use in the manufacture of waferboard and particle board. Wastewater from this plant was discharged to the Kaministiquia River after biological treatment to remove nitrogen. In 1979, a second plant producing phenol-formaldehyde resins was constructed. In April, 1980, the urea-formaldehyde treatment system was accidently poisoned by phenolic waste. Since then, both wastewater discharges are treated through the phenol-formaldehyde biological system. The original treatment unit made inoperable in 1980 is now utilized as a secondary clarifier for both effluents. As of 1988, final effluent was discharged to the municipal sewers. Final effluent does not meet provincial toxicity standards.

Ogilvie Mills Limited (formerly Industrial Grain Products Inc.)

Industrial Grain Products operated a plant which produced starch and gluten from wheat flour; the mill, now operated by Ogilvie Mills is located on the Kaministiquia River, just upstream of the McKellar River. In 1973, a countercurrent recycle system was installed, which reduced the effluent volume by 45%, and reduced concentrations of suspended solids and BOD_5 by about 30%. In 1974, an evaporator was installed to recover bran, a major source of suspended solids in the effluent previously discharged to the

Kaministiquia River. In 1974, three storage tanks were installed to contain process spills, allowing spilled material to be recycled, rather than being discharged. In 1981, the sanitary sewage system was connected to the municipal sewage collection system. An anaerobic/aerobic wastewater treatment plant was constructed in 1981. This facility had severe commissioning problems, and was unable to reduce BOD_5 discharges from approximately 7000 kg/day to approximately 900 kg/day, as planned. In 1985, the wastewater plant was converted to thermophilic operation, resulting in a significant improvement in effluent quality. The company is presently investigating discharging treated effluent to the municipal sewer. Provincial toxicity standards are exceeded due to the anaerobic characteristic of this effluent.

City of Thunder Bay Wastewater Pollution Plant

In 1973, the City of Thunder Bay operated two primary wastewater treatment plants. The north ward plant, which discharged to the McIntyre River (see Section 3.2.3) was chronically overloaded. The south ward plant which discharged to the Kaministiquia River near the mouth was also periodically overloaded as a result of storm runoff from combined sewers. In 1978, the expansion of the south ward waste water treatment plant was completed and sewage from the north ward were redirected to it. Since then all sewage from the city has been directed to and treated at the south ward plant. The plant has a design capacity of 109,000 m^3/day, and is capable of partially treating flows up to 218,000 m^3/day.

In conjunction with the treatment plant expansion, several large trunk sewers were installed in both the north and south wards of the city. As a result, direct sewage discharges to Lake Superior and the Kaministiquia River were eliminated. The older sections of the south ward system are serviced by combined sewers and during storms, high flows are experienced at the sewage treatment plant. The City has initiated a combined sewer separation program in the south ward to reduce volumes of storm water entering the treatment plant.

Raw sewage from the Thunder Bay system is dilute and difficult to treat effectively. However, treatment efficiencies for BOD_5 and suspended solids are within Provincial objectives. In January, 1982, alum was added to the process to remove phosphorus from the effluent. Some operational problems were experienced with alum, and ferric chloride was substituted. Yearly averages for phosphorus in the effluent are above the 1 mg/ℓ objective.

Flow in the Kaministiquia River

The Kaministiquia River rises in Dog Lake, situated about 40 km northwest of Thunder Bay, and drains an area of approximately 6,800 km^2. The Shebandowan Lakes also feed the river via the Shebandowan River. Discharges from these lakes are regulated to produce hydroelectric power. Ontario Hydro regulates flow through control and operation of the Silver Falls Dam and Generating Station, the Shebandowan Lake Dam and the Kakabeka Falls Dam and Generating Station. Through an agreement with the Ministry of the Environment, Ontario Hydro maintains a minimum flow of 17 m^3/s or greater at Kakabeka Falls Dam and Generating Station during the summer months (April 15 to November 14), and 11.5 m^3/s or greater during the winter months (November 15 to April 14). However, during hot, dry summers, when river flows are low and water temperatures are high, dissolved oxygen levels in the Kaministiquia River can fall below critical levels (less than 4 mg/ℓ) and may cause fish kills. Recently, these conditions have occurred in the summers of 1977, 1980, 1987 and 1988. Under summer low flow conditions, water quality in the Kaministiquia River is strongly influenced by the small volume of river water available to dilute effluent from Canadian Pacific Forest Products.

Water quality, lower Kaministiquia River
(Figs. 75-106 and Table 6)

The period of record for water quality varies from station to station along the lower Kaministiquia River and its deltaic channels, the Mission and McKellar Rivers. Data for the following stations date from 1968: the Kaministiquia River at Hwy 17 (background) and the Turning Basin; at the forks of the Mission River and near the mouths of the McKellar and Mission Rivers. Stations were added at Hwy 61B and on the McKellar River (at 104th St.) in 1972, and at the mouth of the Kaministiquia River in 1978. Water quality in the Turning Basin is sampled only during the period of May through October each year. For some parameters these differences may bias comparisons of median values among stations, especially between the Turning Basin and Hwy 61B. Despite this it is possible to develop a general picture of water quality trends along the Kaministiquia River.

Conventional Parameters

BOD_5 levels were highest at the Turning Basin (range 5-50 mg/ℓ; median 13 mg/ℓ). BOD_5 levels also were high at Highway 61B but were lower downstream at the station above the forks of the Kaministiquia and Mission Rivers. At the mouth of the Kaministiquia River BOD_5 levels were consistently below 15 mg/ℓ.

Chlorides and conductivity showed a similar pattern of decreasing values from upstream stations to the river mouths. Values increased at the Turning Basin, decreased slightly at Hwy 61B and above the Mission River. Conductivity declined slightly (from 157 to 140 mg/ℓ) at the mouth of the Kaministiquia River. Chlorides fell from a median value of 11.5 mg/ℓ at the Turning Basin to 7.2 at the mouth.

Values at the other river mouths showed various levels of reduction relative to upstream stations. BOD_5, chlorides and conductivity remained relatively high at the mouth of the Mission River. Median values of BOD_5 in the McKellar River varied from 3.7 to 2.4 mg/ℓ between the station at 104th St. and the mouth. Chlorides declined from 8.0 to 6.0 mg/ℓ, and conductivity fell from 134 to 125 mg/ℓ.

These patterns differ somewhat from those reported by Klose (1988). These differences can be attributed to sampling frequency and duration. The data generated by Klose (1988) was based on an intensive 72-hour sampling period in August of 1986.

BOD_5, chlorides and conductivity all followed a similar temporal pattern at a given location. All three parameters showed high values throughout the 1970's with peaks in 1971 or 1972, 1977, 1980, and 1987, with lows in the mid 1970's, 1978, and 1985. The specific year when values peaked or reached a low varied slightly from station to station.

There was a marked decline in BOD_5, chlorides and conductivity at the Turning Basin in 1982, that persisted until 1987. That decline coincided with improvements to the closed-cycle kraft mill at Canadian Pacific Forest Products; the higher levels in 1987-1989 coincided with low flow years. Analysis in this report cannot distinguish the influence on these parameters of flow reduction, improvements at CPFP, and changes in discharges to the river further downstream.

Values for pH remained lower (median values of 7.1 or 7.2) at all downstream stations than upstream (-0108-002-) where the median value was 7.4.

Median values for suspended solids (RSP) at the Turning Basin and Hwy 61B (9 and 10 mg/ℓ, respectively) were double upstream values and remained high downstream at the forks and at the mouth of the Mission River. Some decline (to median values of 6 and 8 mg/ℓ) occurred along the McKellar River and at the mouth of the Kaministiquia River.

Phosphorus increased from a median value of 0.016 mg/ℓ at Hwy 61 to 0.044 mg/ℓ at the Turning Basin. It increased even further in all the branches, especially at McKellar at 104th St. (to a median value of 0.062 mg/ℓ) and the mouth of the Kaministiquia River, downstream of the waste water treatment plant. No data are available from this station (-0108-004-) that pre-date the expansion of the WWTP. The data fluctuate with no obvious trend, however, ammonia and nitrogen increased at the mouth.

Microbiological quality of the water at downstream sites was very poor. Since 1981, total coliform levels frequently were greater than 1000 counts/100 ml at all locations. Median values range from 26000 counts/100 ml at the Turning Basin (summer data only) to 3900 at the mouth of the McKellar River. Fecal coliform levels (discontinued in 1984) also were high, especially at Hwy 61B, the forks of the Mission, and at the mouth of the Kaministiquia River (downstream from the WWTP).

Fecal coliform counts in pulp mill effluents can be misleadingly high. Sample bias can be attributed to *Klebsiella*, a bacteria normally associated with woody material. *E. coli* and *Pseudomonas*, both bacteria associated with human waste, were relatively low at Hwy 61B, suggesting that the high fecal counts at Hwy 61B (median of 1000 counts/ml) were not from sewage.

Metals

Surface waters have been analyzed for metals since 1977, with minor exceptions. Data on mercury are available only for the station at Hwy 61B. Cadmium, copper, and mercury have been analyzed as often as 63 times per year at this site. The majority of other parameters and locations were sampled almost monthly, except the Turning Basin, where few samples for metals were obtained.

In general, background levels (median values) at Hwy 61 are relatively high for aluminum, cadmium, copper, iron, manganese, and zinc. At Hwy 61B median levels increased by a factor of no more than two above background. These slightly elevated values generally persisted along the Mission River; they usually declined to background levels along the McKellar River and at the mouth of the Kaministiquia River. Exceptions were maximum values for copper, iron and zinc that were relatively high at the mouth of the Kaministiquia River in 1989, when levels elsewhere were relatively low. A general decline in levels of cadmium, copper and zinc has occurred in recent years. Individual metals are described below in more detail.

Cadmium often was not detectable, but occasionally exceeded the PWQO of .0002 mg/ℓ. Cadmium levels in the McKellar River were above guidelines on five occasions during 1989 (maximum value; .0005 mg/ℓ).

Aluminum concentrations were above provincial guidelines (PWQG = 0.075 mg/ℓ at pH 6.5 to 9.0 measured in clay free samples). Median background levels were 0.18 mg/ℓ, and doubled to 0.36 at Hwy 61B. Levels fell to background levels at the mouth of the Kaministiquia River and on the McKellar River, but remained high at the stations above and on the Mission River.

Copper levels below Hwy 61 were slightly elevated above background; all stations report exceedances (PWQO of 0.005 mg/ℓ) in most years. There was a decline in copper values in 1988 and 1989, except at the mouth of the Kaministiquia River.

Iron frequently exceeded the PWQO (0.3 mg/ℓ) at several locations. Medians ranged from 0.44 mg/ℓ at the upstream station (-0108-002-) to 0.63 mg/ℓ at Hwy 61B. Levels declined to approximately background values at the mouths of the Kaministiquia and McKellar Rivers, but not at the stations above and on the Mission River. Most of the highest values recorded in the 1980's occurred between 1983 and 1986. A smaller peak was observed in 1988. Maximum levels were down in 1989, except at the mouth of the Kaministiquia River.

Manganese levels ranged from a median of 0.017 mg/ℓ at the background station to .50 mg/ℓ at Hwy 61B. Although values were lower at the mouths of the Kaministiquia and McKellar Rivers, they remained approximately double background concentrations.

Mercury (monitored only at Hwy 61B) was below detection most of the time, and only exceeded the PWQO (0.2 ug/ℓ) in 1977. There is some question about the reliability of these early data (refer to Section 3.4). Mercury levels from 0.01 ug/ℓ to 0.14 ug/ℓ have been detected at least once yearly since 1983. Six samples (out of 36) produced levels between 0.05 and 0.14 ug/ℓ in 1989.

Zinc concentrations increased from a median value of 0.004 mg/ℓ at Hwy 61 to 0.007 mg/ℓ at Hwy 61B; it is marginally lower at some downstream stations. Levels occasionally exceeded the revised PWQO of 0.016 mg/ℓ at all sites. The PWQO in place during the period of the report was 0.030 mg/ℓ; this value was exceeded a few times over the years. The highest value reported was 0.23 mg/ℓ, in 1979, at the forks of the Mission River. In general, the background station showed more extreme high values even though median and mean values were lower. There has been a general decline in zinc levels since 1982 or 1983.

Arsenic, cobalt, chromium, lead, and nickel, show only rare (if any) exceedances of the PWQO's, and are not discussed further.

Sources of the metals discussed above have not been identified, with the following exceptions. Alum, a derivative of aluminum, is used at Canadian Pacific Forest Products, and was used during 1981 and 1982 at the Thunder Bay WWTP. Sources of mercury include a chlor-alkali plant that was located adjacent to the Turning Basin until 1974. Other potential contributors of metals include the municipal storm sewers that discharged into the Kaministiquia River until the late 1980's, scrap metal yards, Valley Camp and Ontario Hydro on the Mission River. It is not possible to relate fluctuations in metal values to abatement activities.

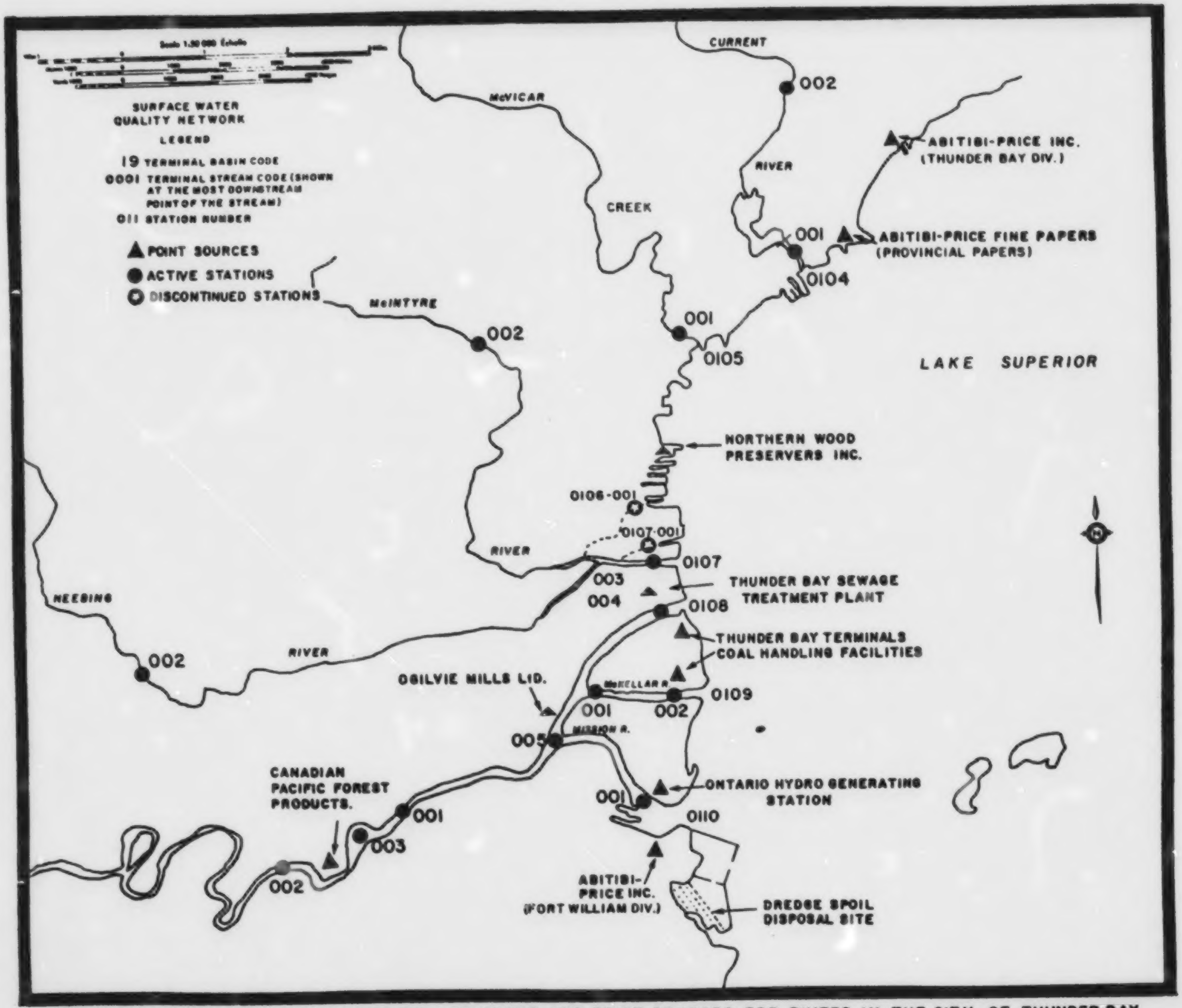
SURFACE WATER
QUALITY NETWORK
LEGEND
19 TERMINAL BASIN CODE
0001 TERMINAL STREAM CODE (SHOWN AT THE MOST DOWNSTREAM POINT OF THE STREAM)
011 STATION NUMBER
▲ POINT SOURCES
● ACTIVE STATIONS
○ DISCONTINUED STATIONS
CURRENT
RIVER
McVICAR
CREEK
McINTYRE
RIVER
NEEBING
RIVER
McKELLAR R.
MISSION R.
LAKE SUPERIOR
ABITIBI-PRICE INC. (THUNDER BAY DIV.)
ABITIBI-PRICE FINE PAPERS (PROVINCIAL PAPERS)
NORTHERN WOOD PRESERVERS INC.
THUNDER BAY SEWAGE TREATMENT PLANT
THUNDER BAY TERMINALS COAL HANDLING FACILITIES
OGILVIE MILLS LTD.
ONTARIO HYDRO GENERATING STATION
CANADIAN PACIFIC FOREST PRODUCTS.
ABITIBI-PRICE INC. (FORT WILLIAM DIV.)
DREDGE SPOIL DISPOSAL SITE
002
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FIGURE 53- WATER QUALITY MONITORING LOCATIONS AND POINT SOURCES FOR RIVERS IN THE CITY OF THUNDER BAY

Table 5: Selected water quality parameters (long term median values) in Thunder Bay rivers.

Station	Alkalinity mg/ℓ	Conductivity mg/ℓ	pH	Suspended Solids mg/ℓ	Total Phosphorus mg/ℓ	Fecal Coliform cnt/100 ml	Copper mg/ℓ	Iron mg/ℓ	Zinc mg/ℓ
Current at 17/11 (-0104-001-)	30	76	7.5	1	0.010	4	0.002	0.40	0.001
Current at Cumberland (-0104-002-)	30	73	7.4	1	0.010	4	0.001	0.45	0.001
McVicar Creek (-0105-001-)	93	264	7.9	5	0.016	32	0.002	0.60	0.007
McIntyre at Hammond (-0106-001-)	83	251	7.3	15	0.365	228	0.007	1.65	0.011
McIntyre at 17 (-0106-002-)	76	185	7.8	2	0.013	20	0.002	0.55	0.001
Neebing at 110th (-0107-001-)	107	272	7.4	10	0.040	116	0.005	1.80	0.006
Neebing at Hwy 17 (-0107-002)	106	245	7.8	4	0.016	24	0.002	0.80	0.002
Neebing - McIntyre Diversion (-0107-003-)	87	254	7.8	4	0.025	90	0.002	0.96	0.004

Table 6: Selected water quality parameters (long term median values) in the lower Kaministiquia River.

Station	BOD mg/ℓ	Chlorides mg/ℓ	Conductivity uhmos	pH	Suspended Solids mg/ℓ	Total Phosphorus mg/ℓ	Zinc mg/ℓ	Total Ammonia/um mg/ℓ
Kam R. U/S (-0108-002-)	1.0	1.6	84	7.4	5	0.016	0.004	0.03
Turning Basin (-0108-003-)	9.6	11.5	157	7.2	9	0.044	0.006	0.02
Highway 61B (-0108-0050)	9.0	11.0	149	7.2	10	0.044	0.007	0.03
at Mission (-0108-005-)	7.0	11.0	150	7.1	10	0.046	0.007	0.02
Kam at Mouth (-0108-004-)	2.0	7.2	140	7.2	6	0.056	0.005	0.08
McKellar at 104 (-0109-001-)	3.7	8.0	134	7.1	8	0.062	0.005	0.04
McKellar Mouth (-0109-002-)	2.4	6.0	125	7.1	6	0.053	0.005	0.05
Mission Mouth (-0110-001-)	6.0	10.0	148	7.1	10	0.044	0.007	0.03

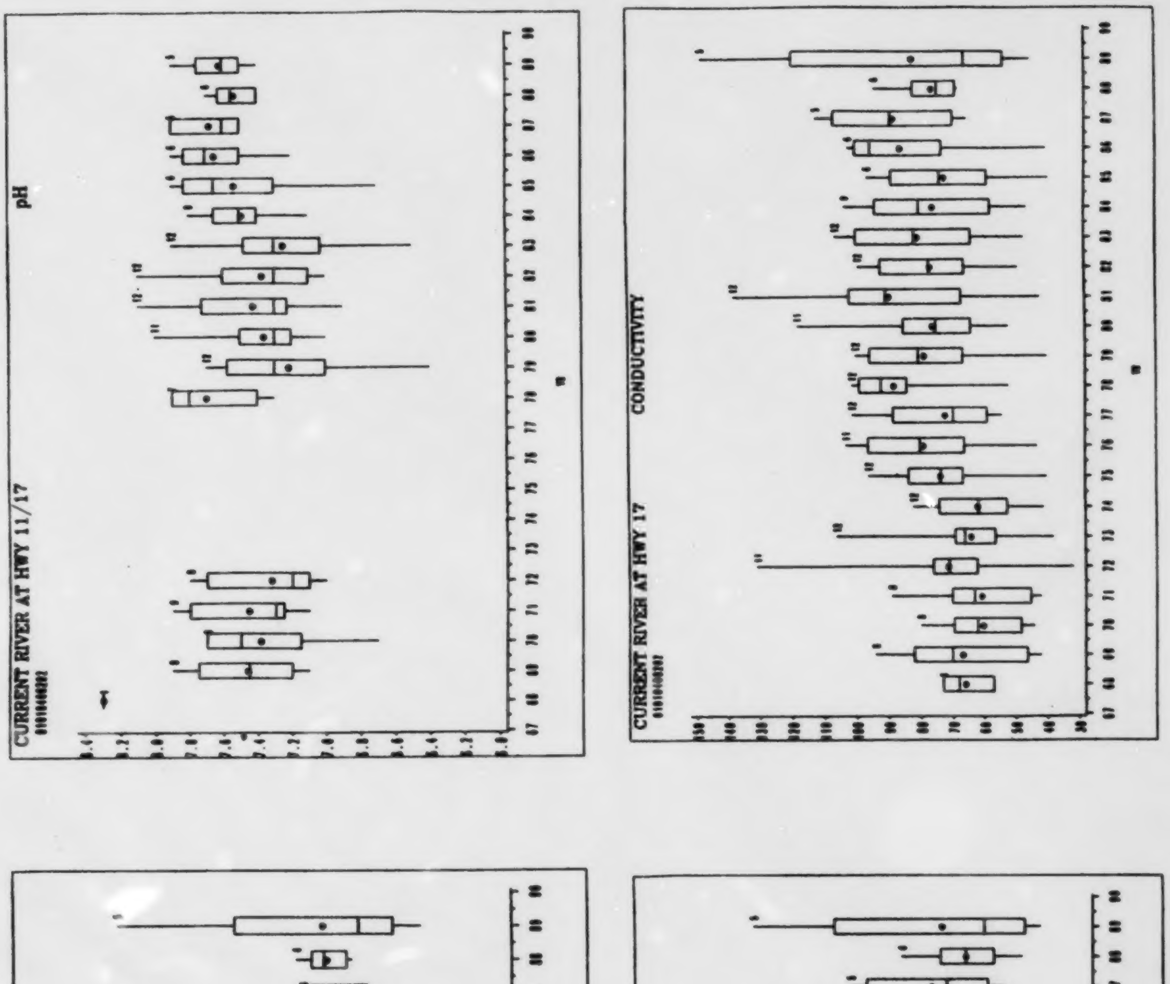


Fig. 54. Water quality in Current River at Hwy. 17.

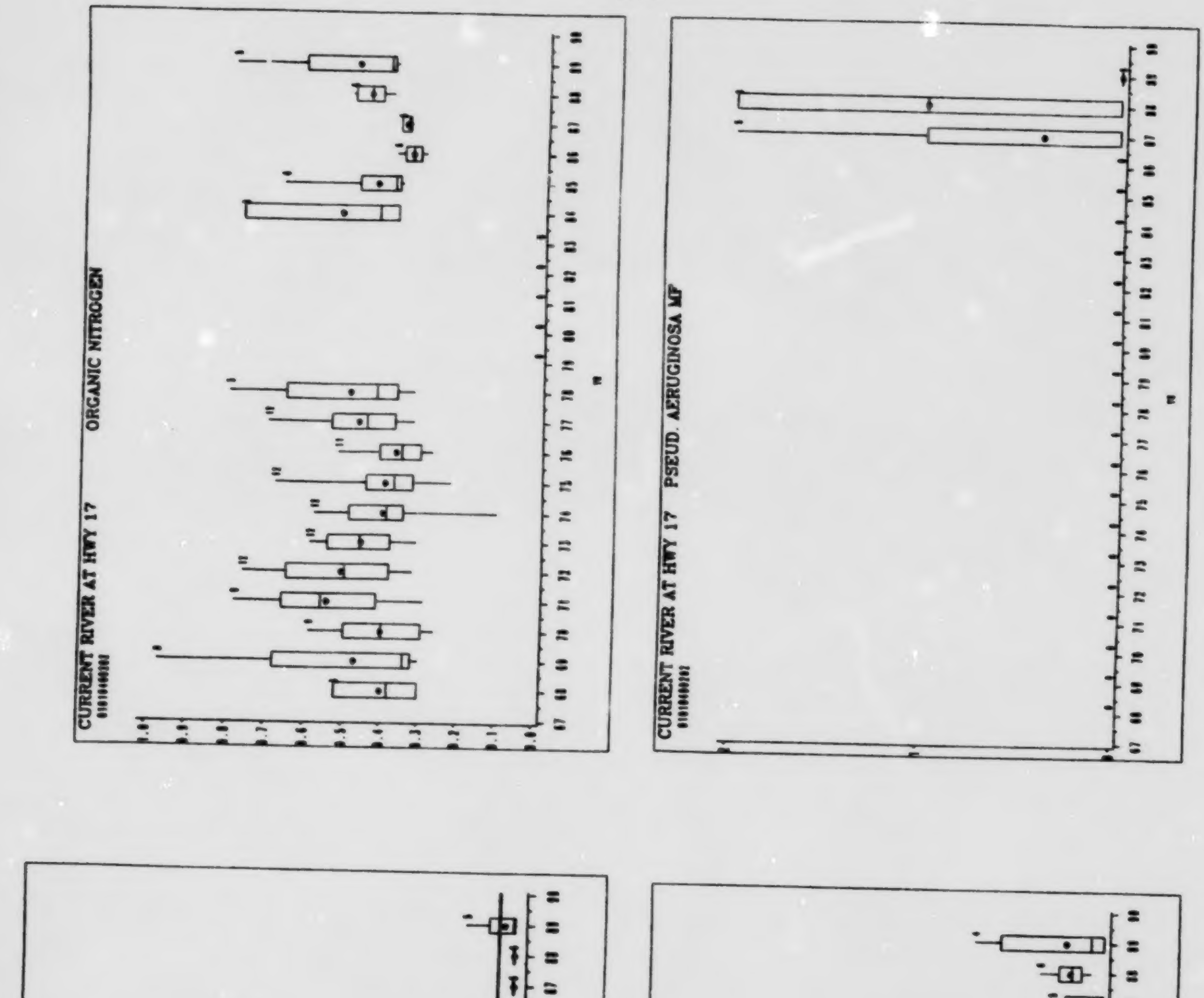


Fig. 55. Water quality in Current River at Hwy. 17.

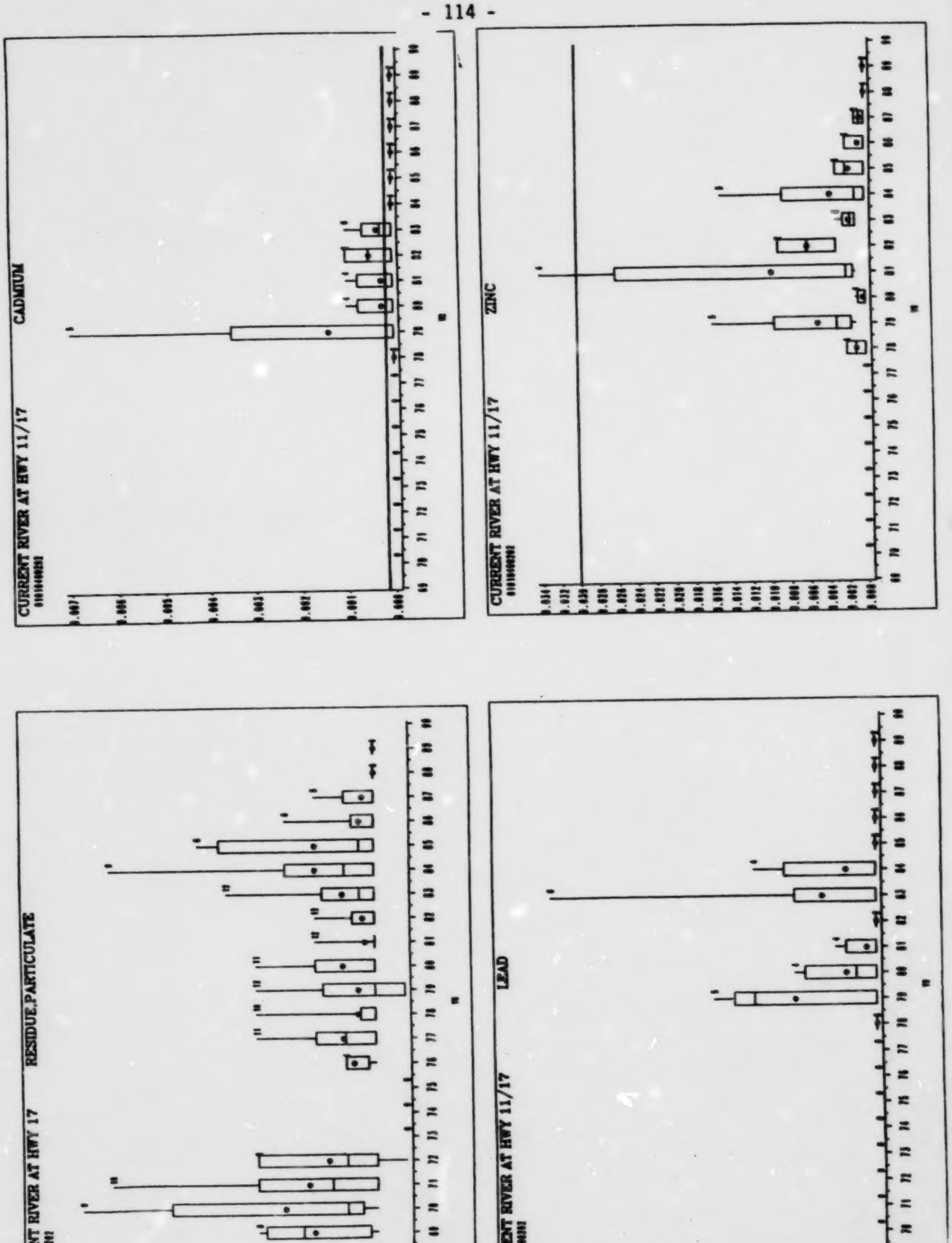


Fig. 56. Water quality in Current River at Hwy. 17.

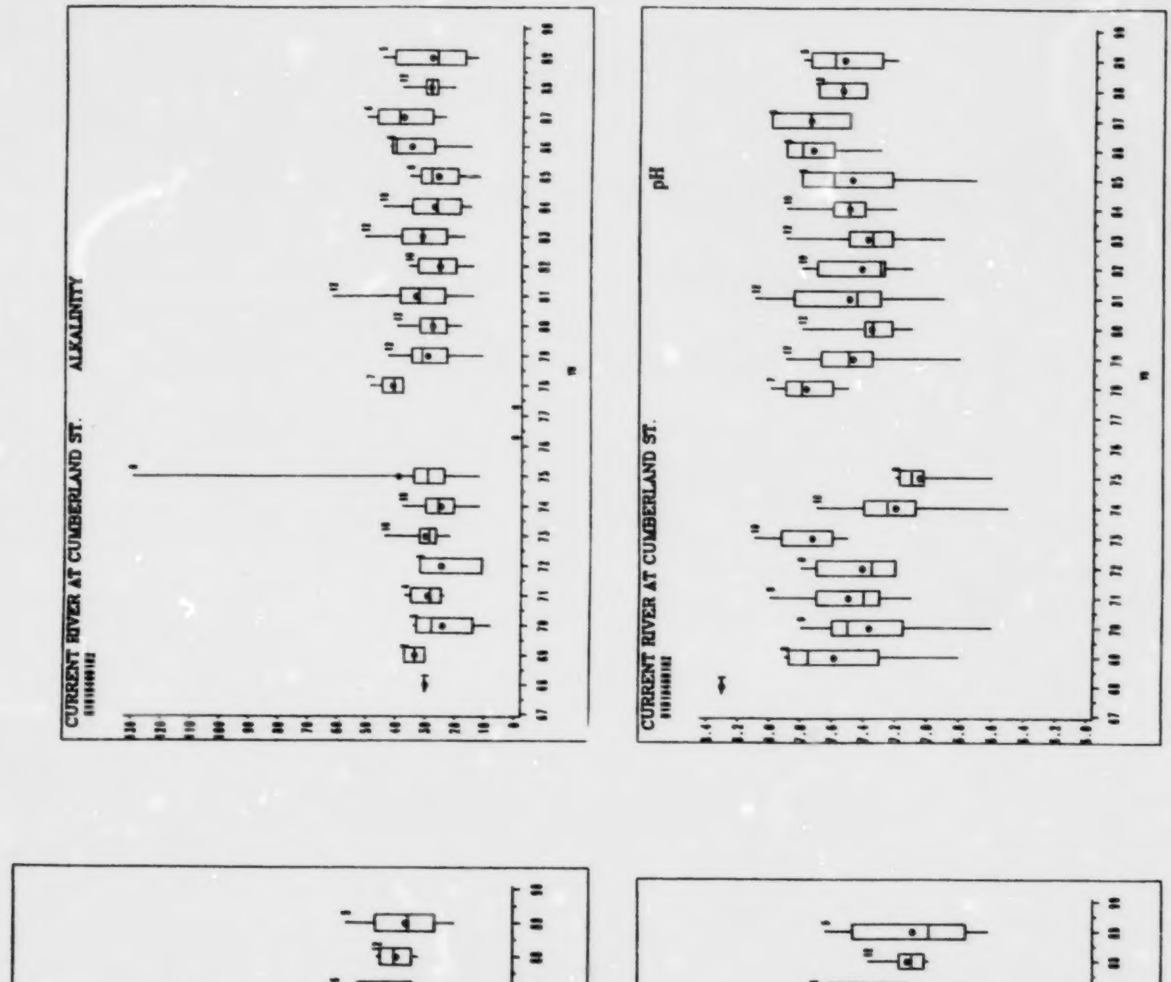


Fig. 57. Water quality in Current River at Cumberland Street.

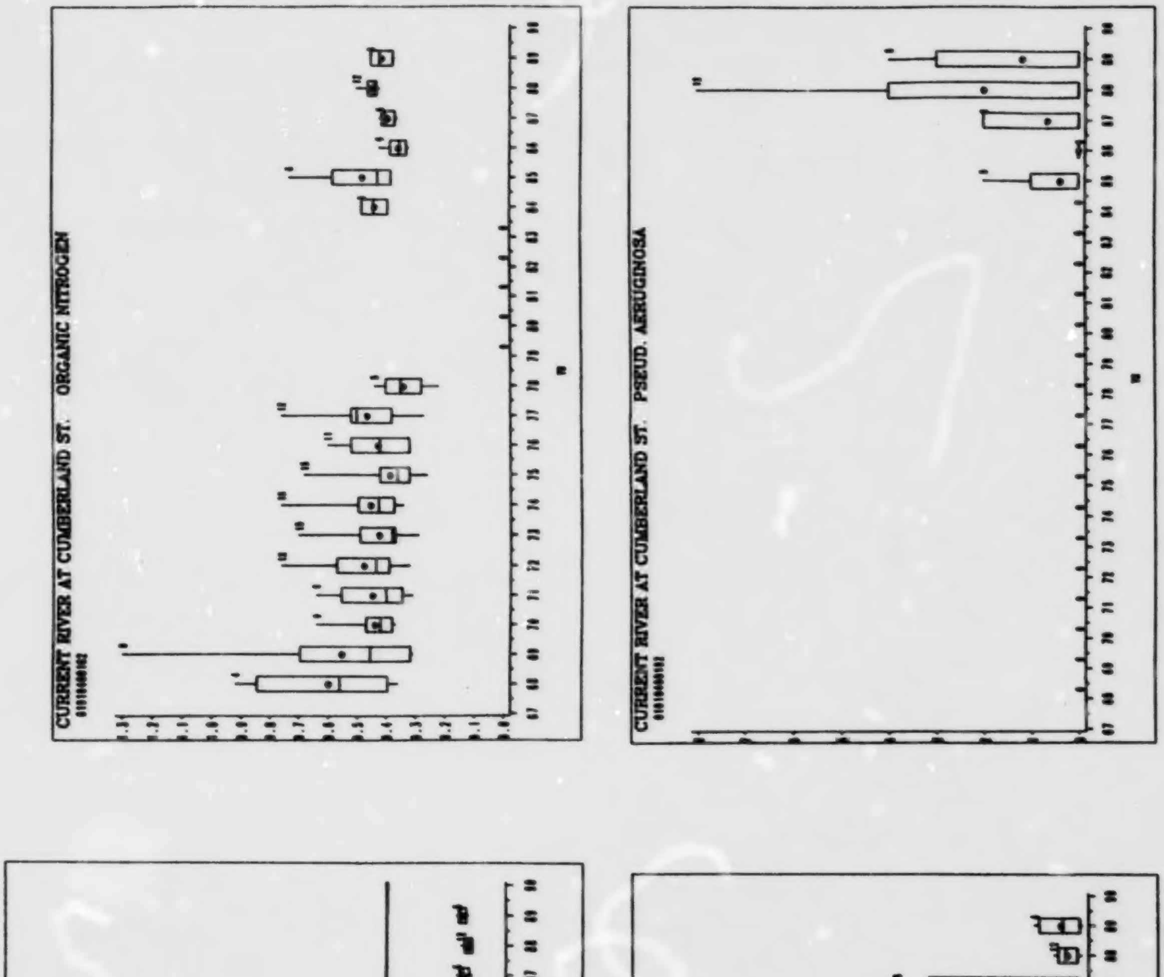


Fig. 58. Water quality in Current River at Cumberland Street.

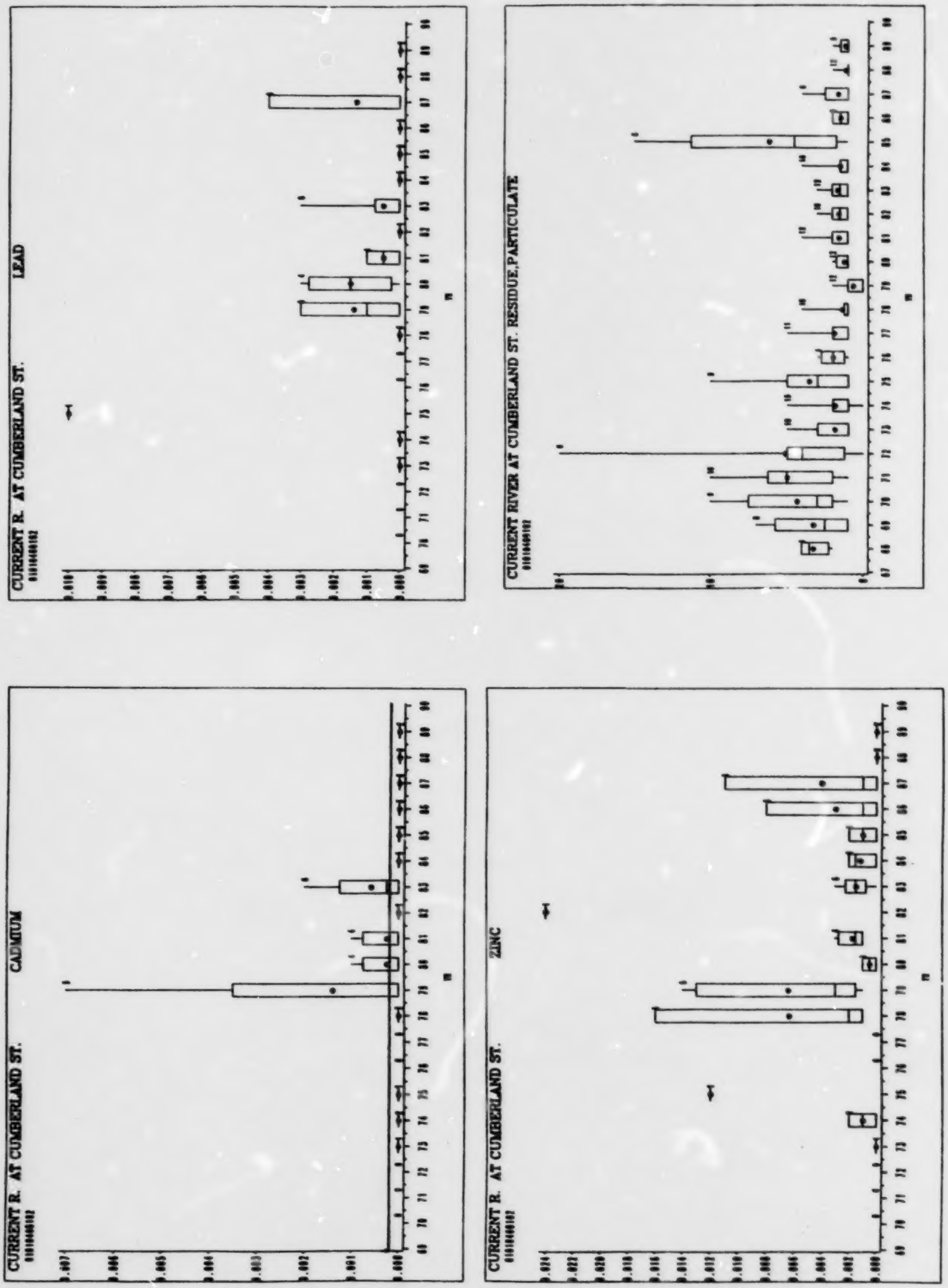


Fig. 59. Water quality in Current River at Cumberland Street.

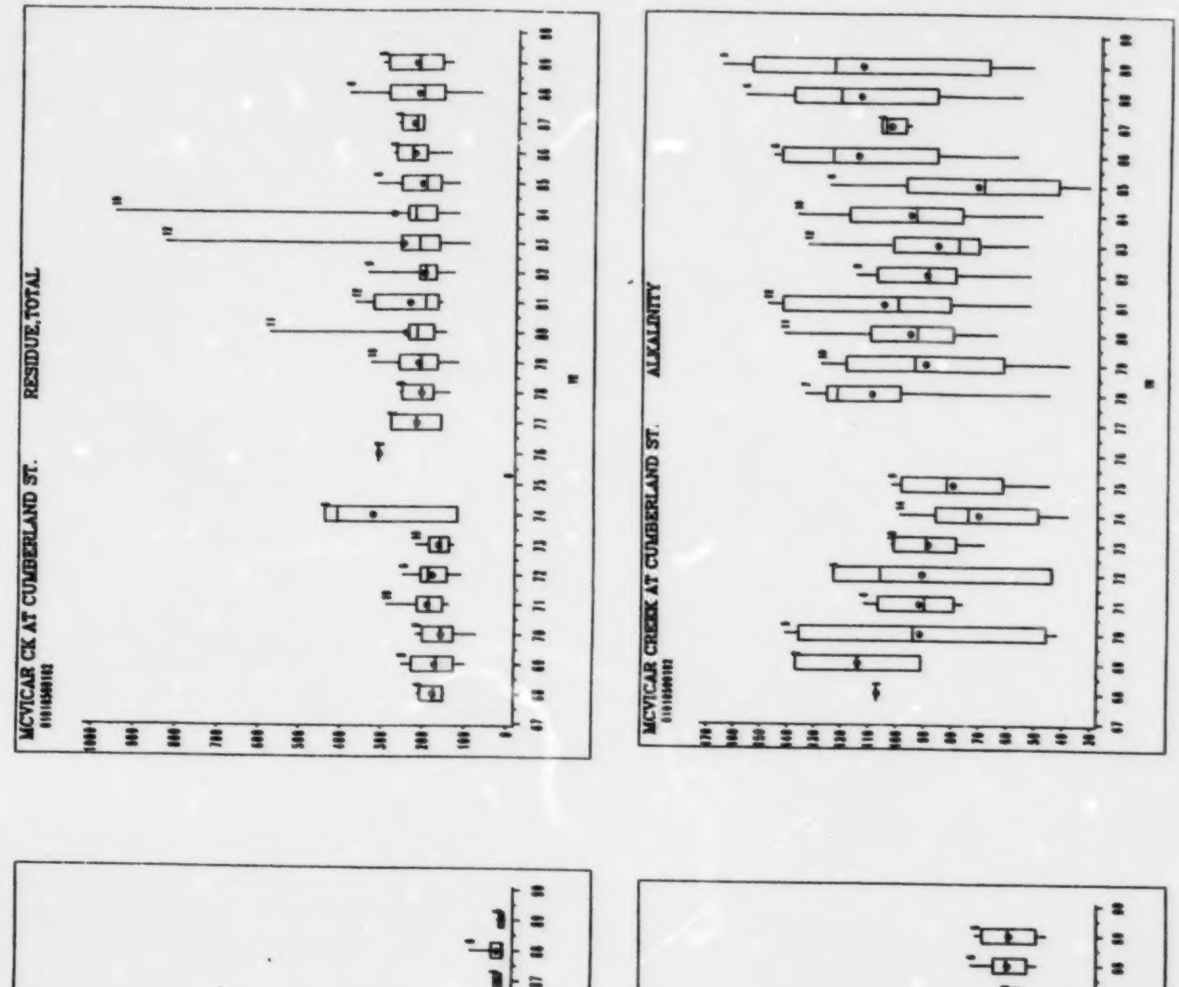


Fig. 60. Water quality in McVicar Creek.

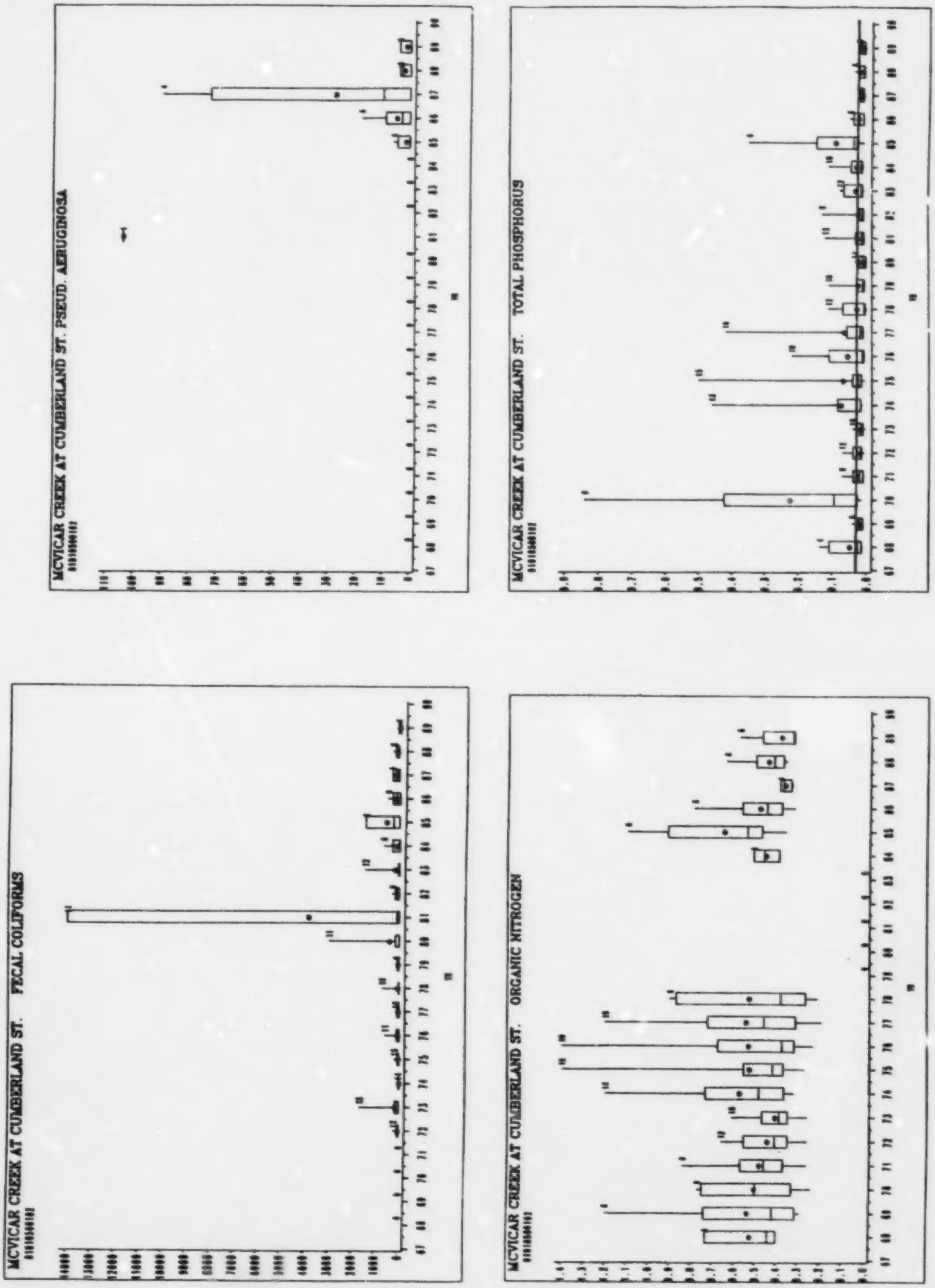


Fig. 61. Water quality in McVicar Creek.

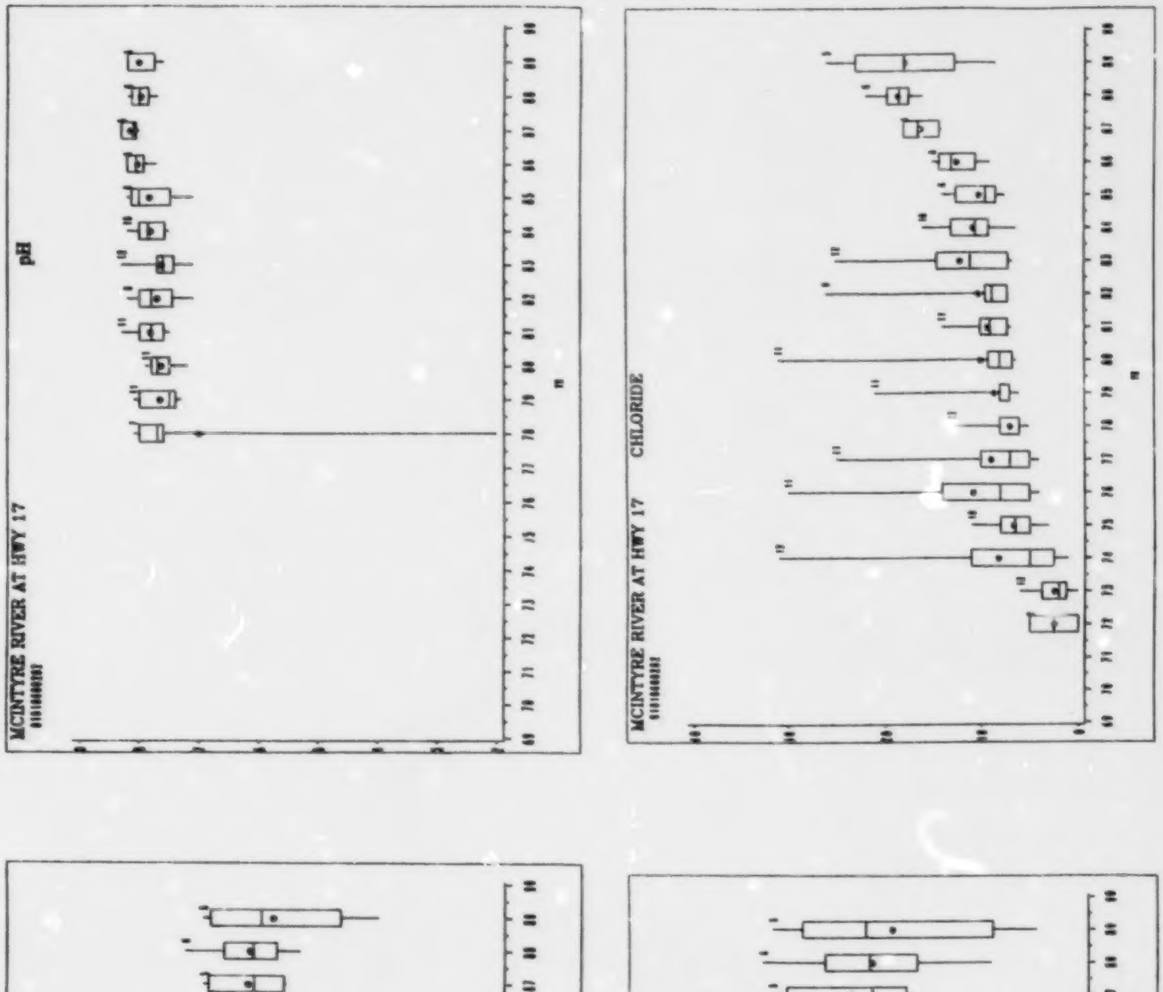


Fig. 62. Water quality in McIntyre River at Hwy. 17.

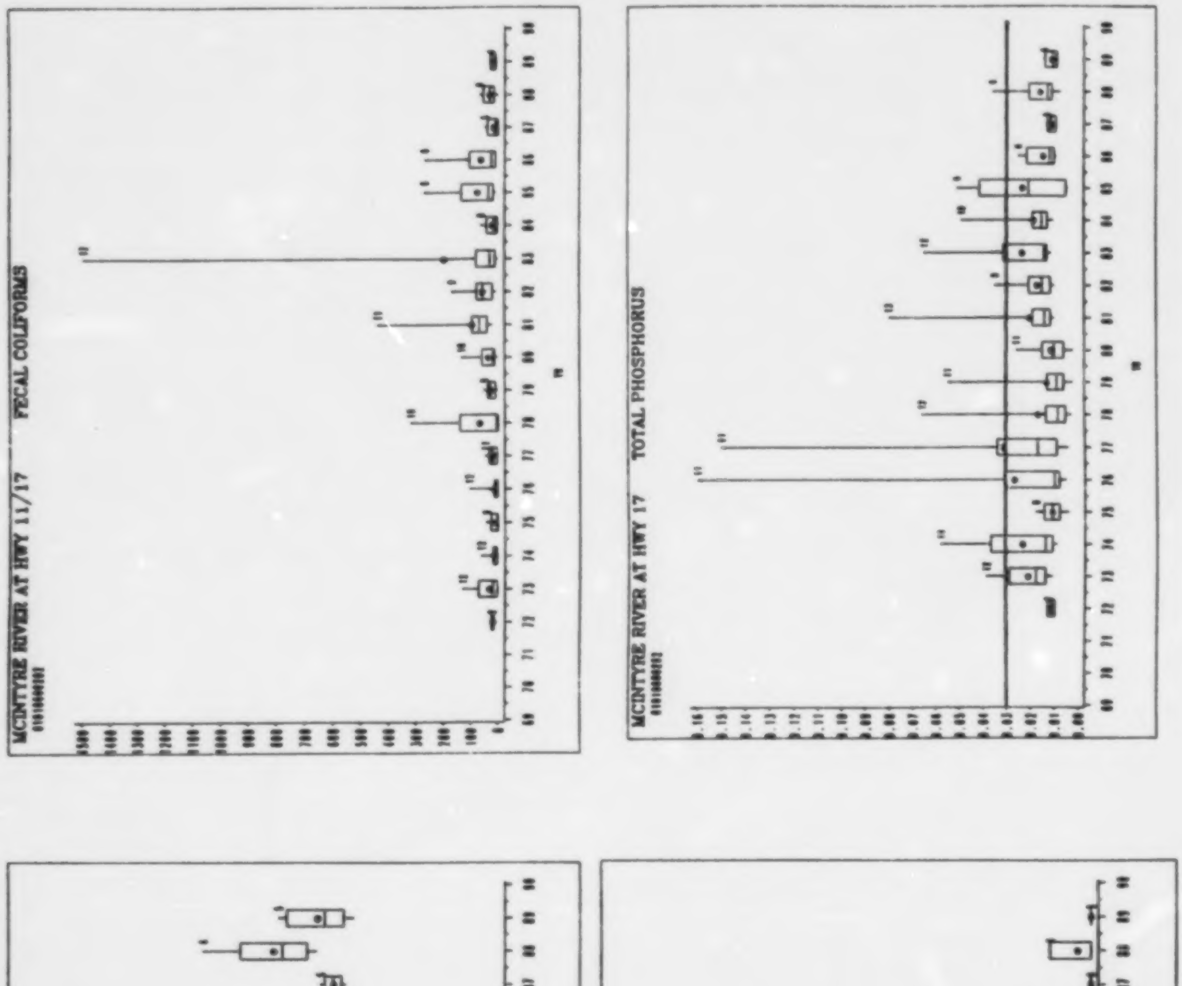


Fig. 63. Water quality in McIntyre River at Hwy. 17.

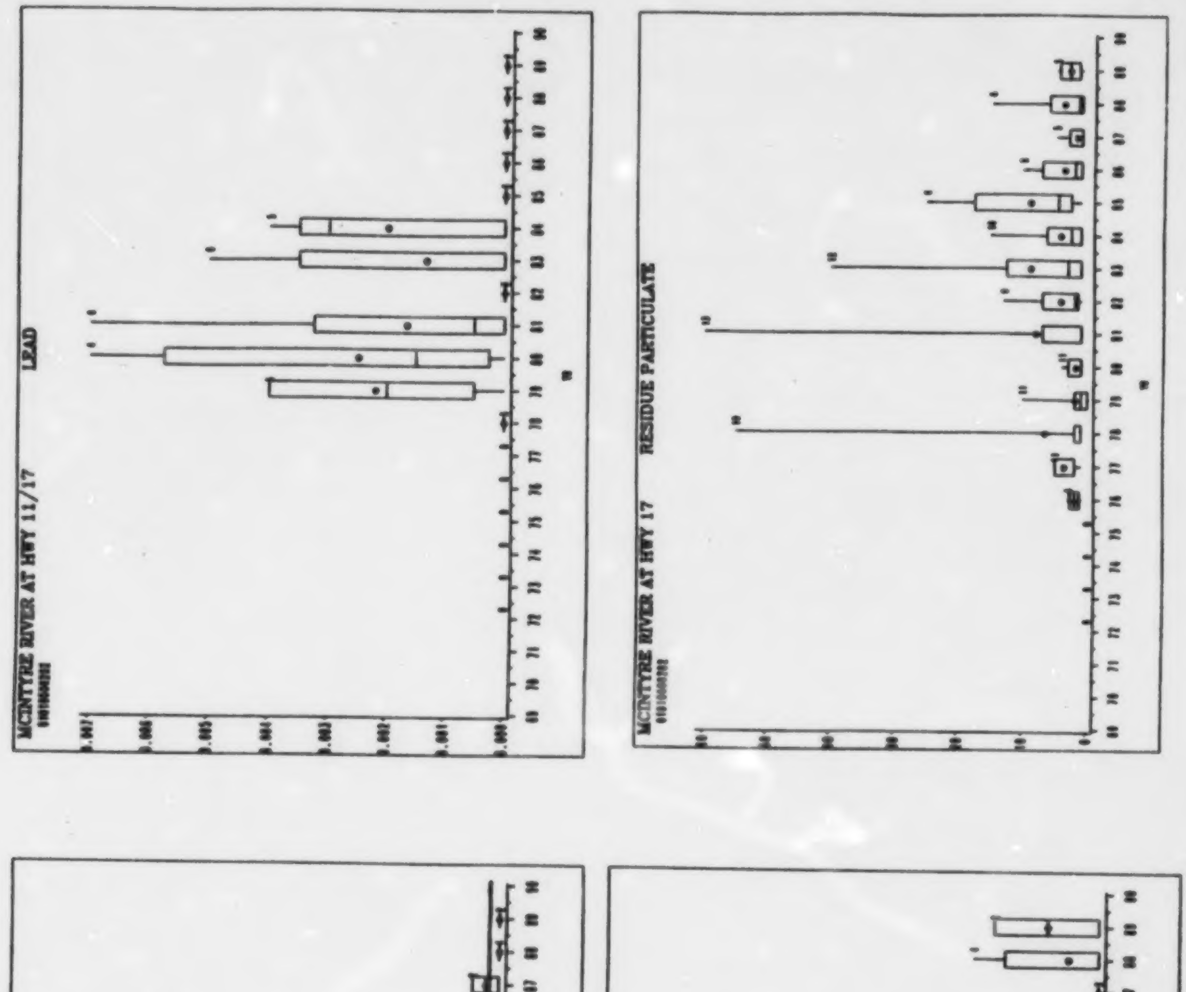


Fig. 64. Water quality in McIntyre River at Hwy. 17.

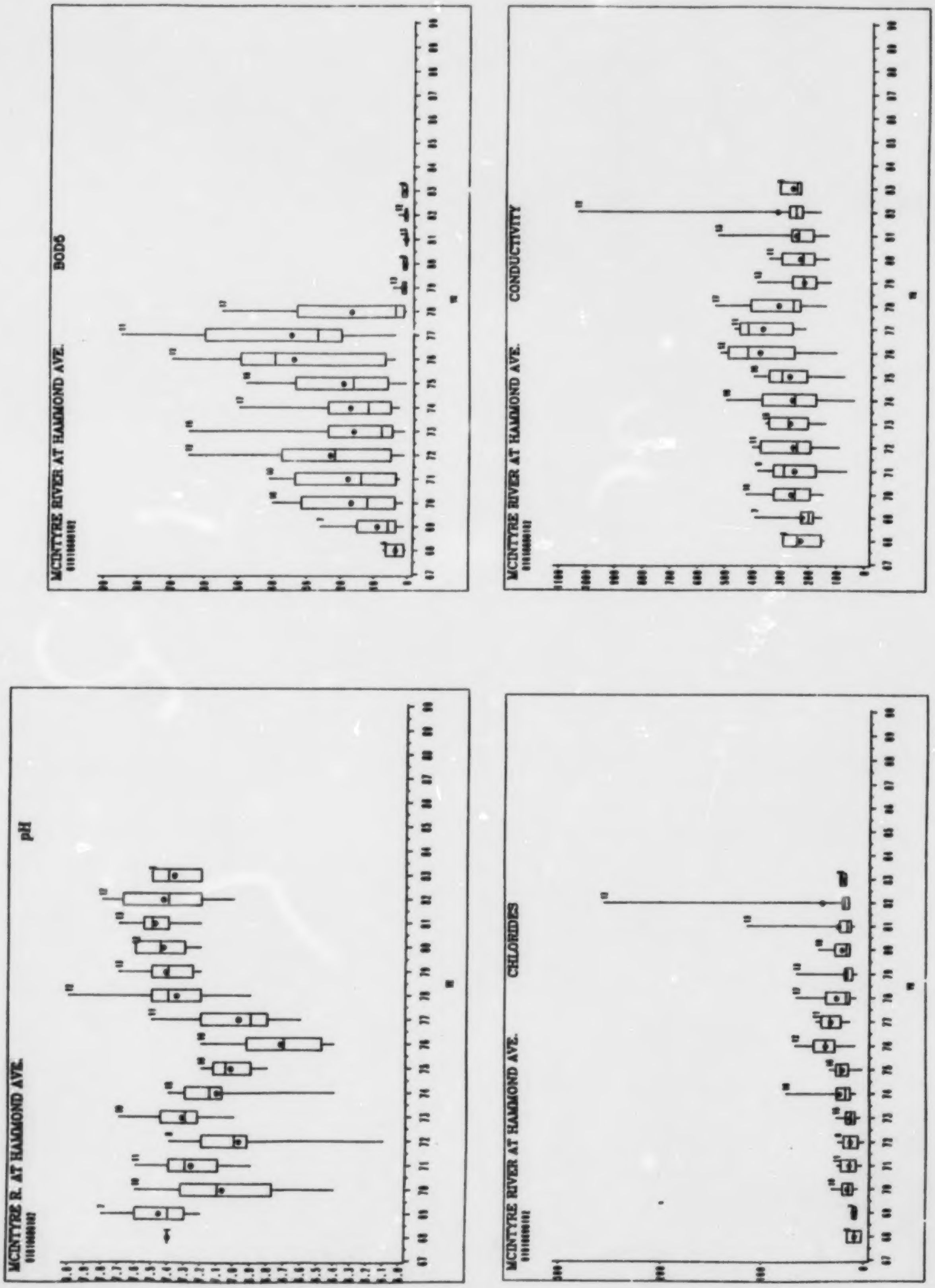


Fig. 65. Water quality in McIntyre River at Hammond Avenue.

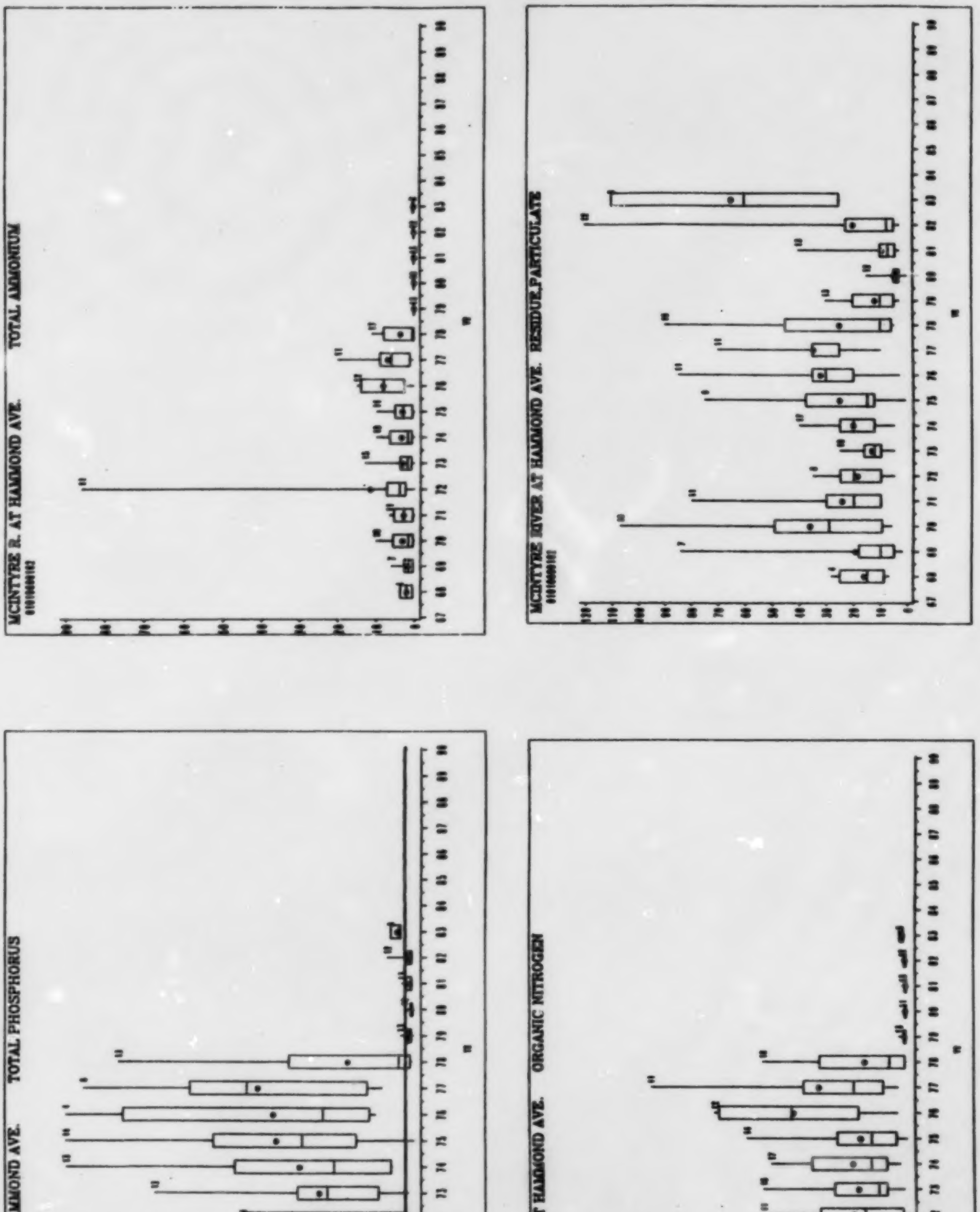


Fig. 66. Water quality in McIntyre River at Hammond Avenue.

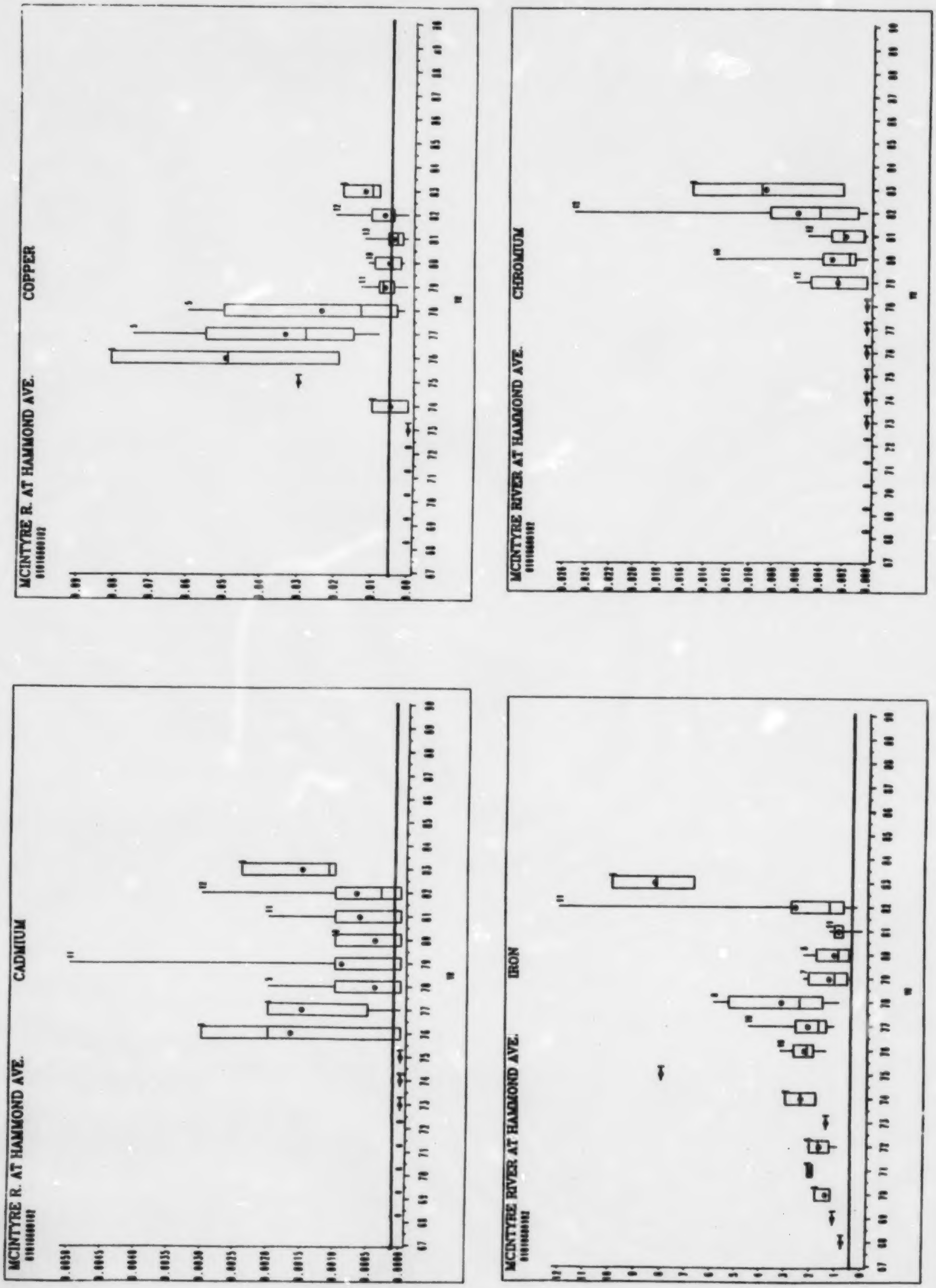


Fig. 67. Water quality in McIntyre River at Hammond Avenue.

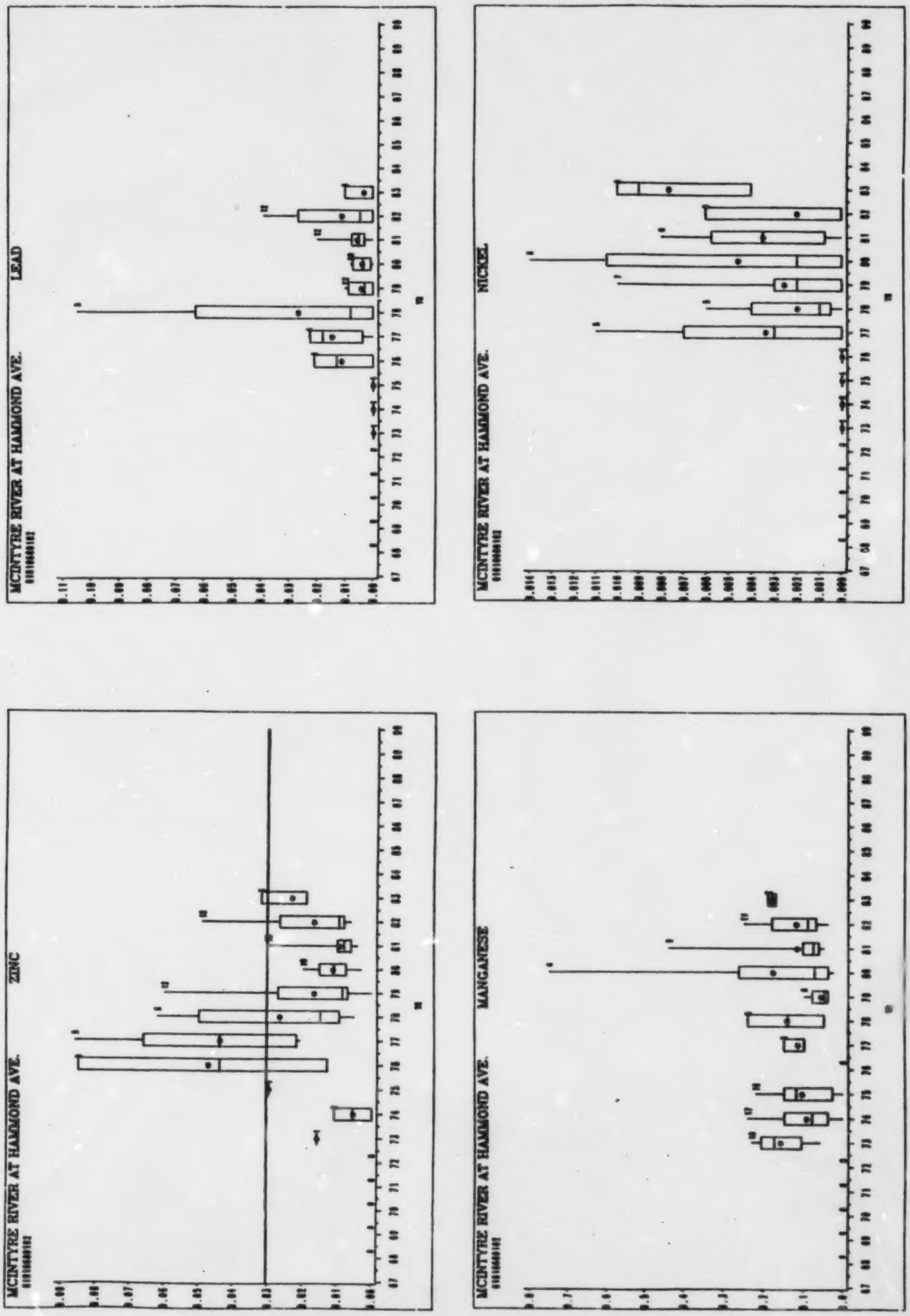


Fig. 68. Water quality in McIntyre River at Hammond Avenue.

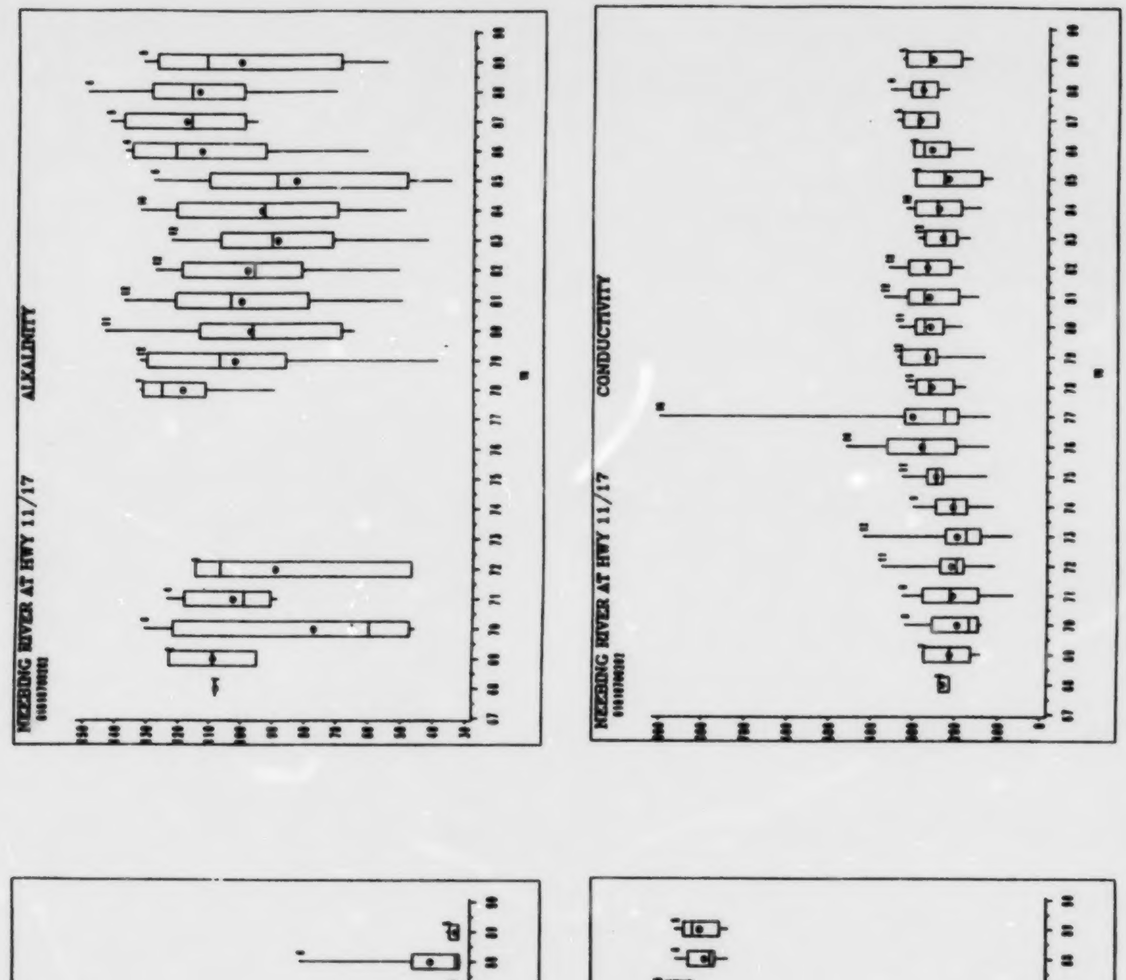


Fig. 69. Water quality in Neebing River at Hwy. 17.

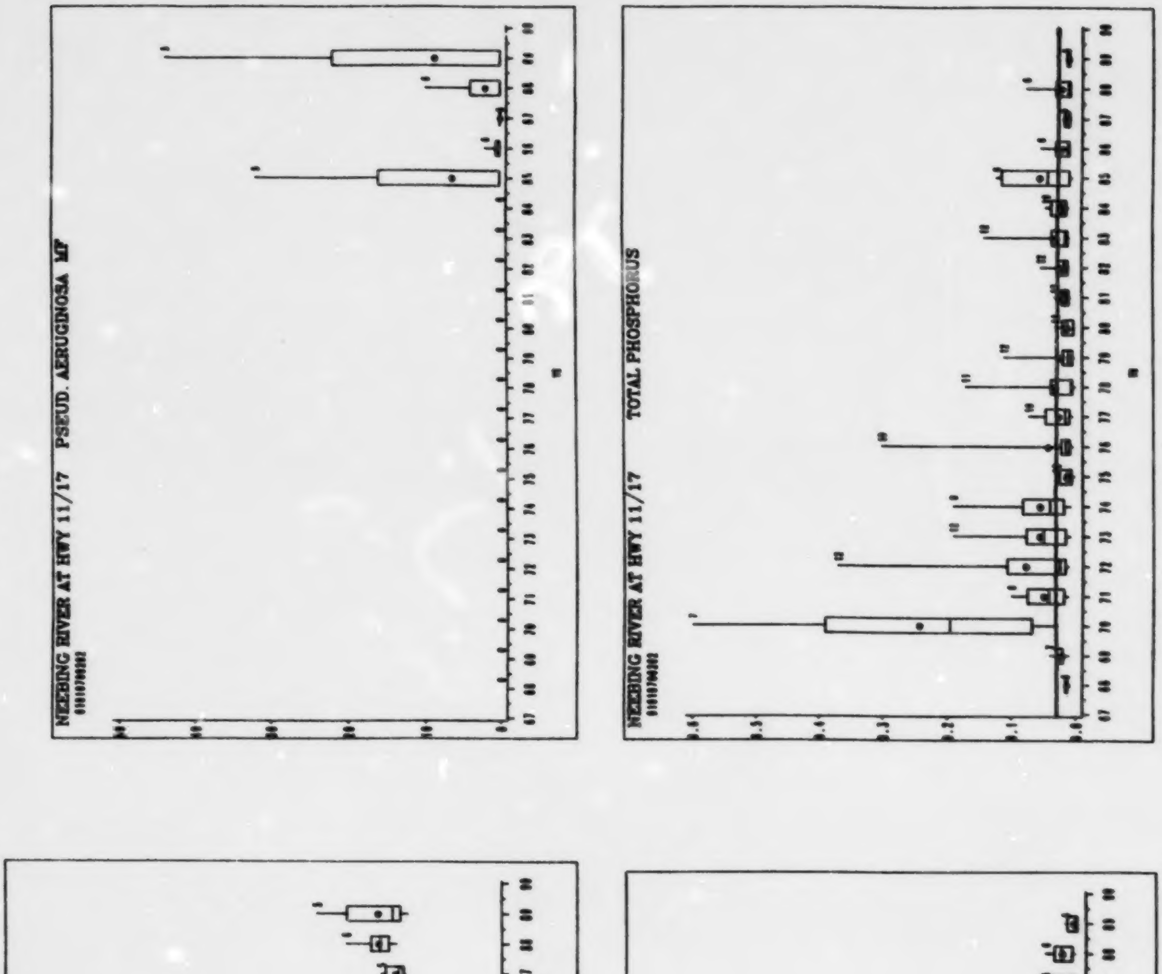


Fig. 70. Water quality in Neebing River at Hwy. 17.

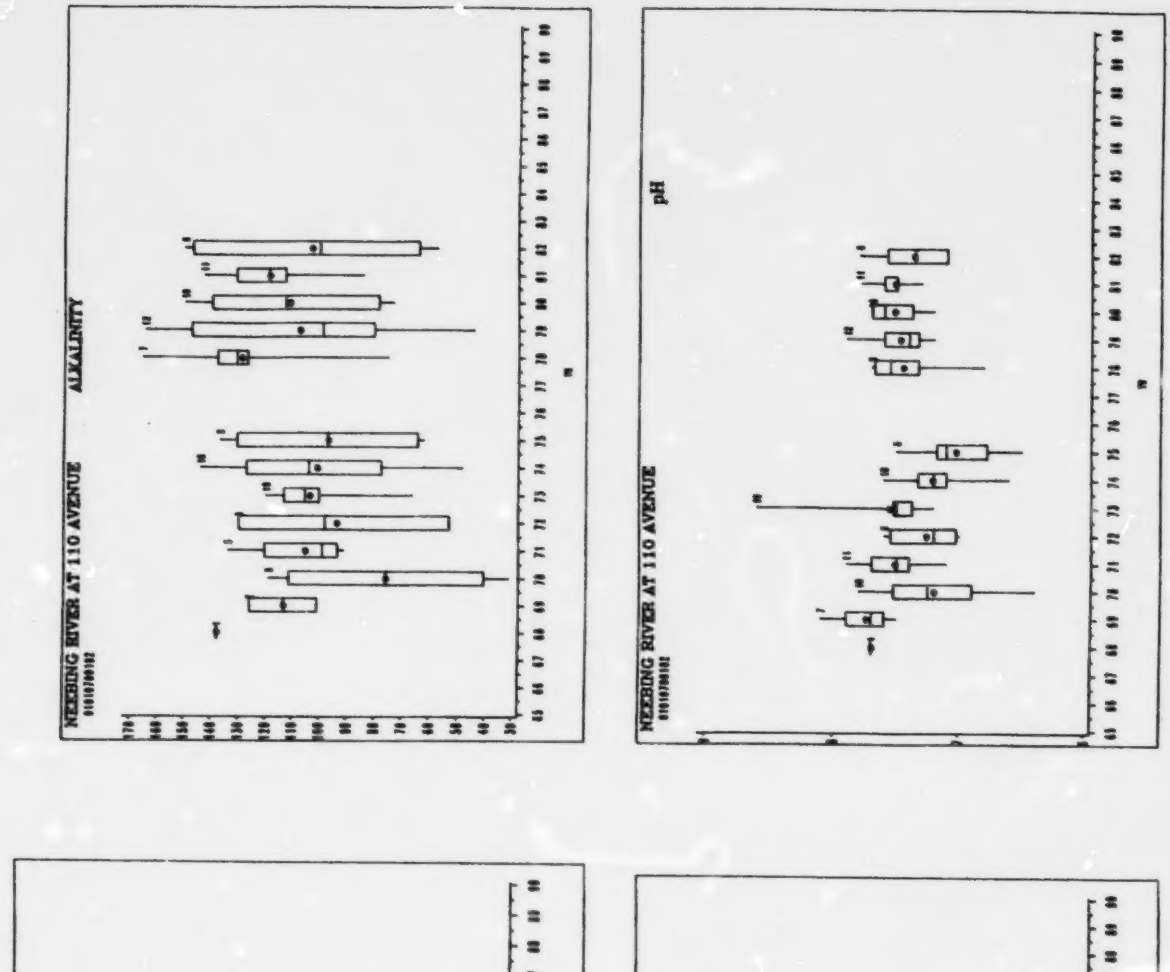


Fig. 71. Water quality in Neebing River at 110 Avenue.

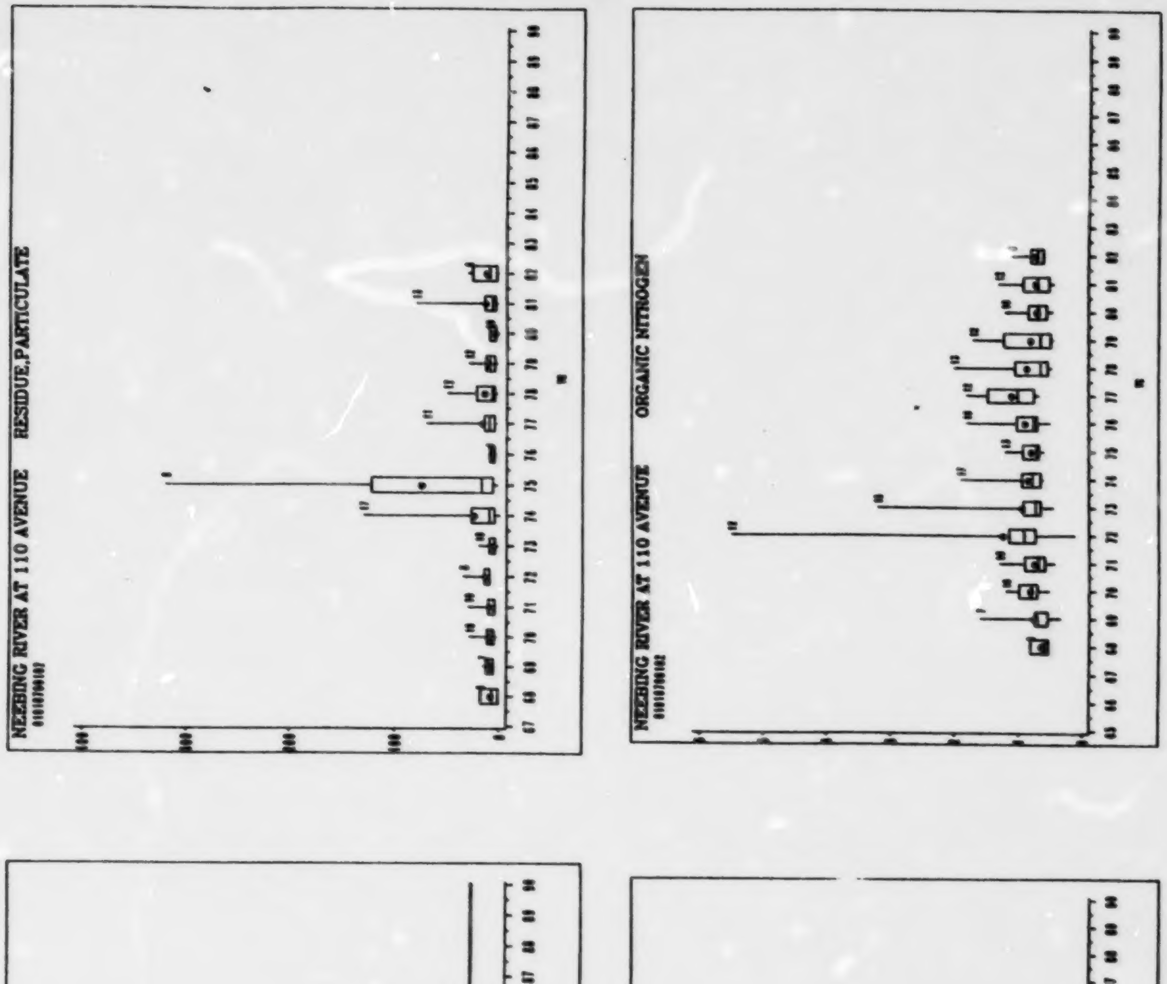


Fig. 72. Water quality in Neebing River at 110 Avenue.

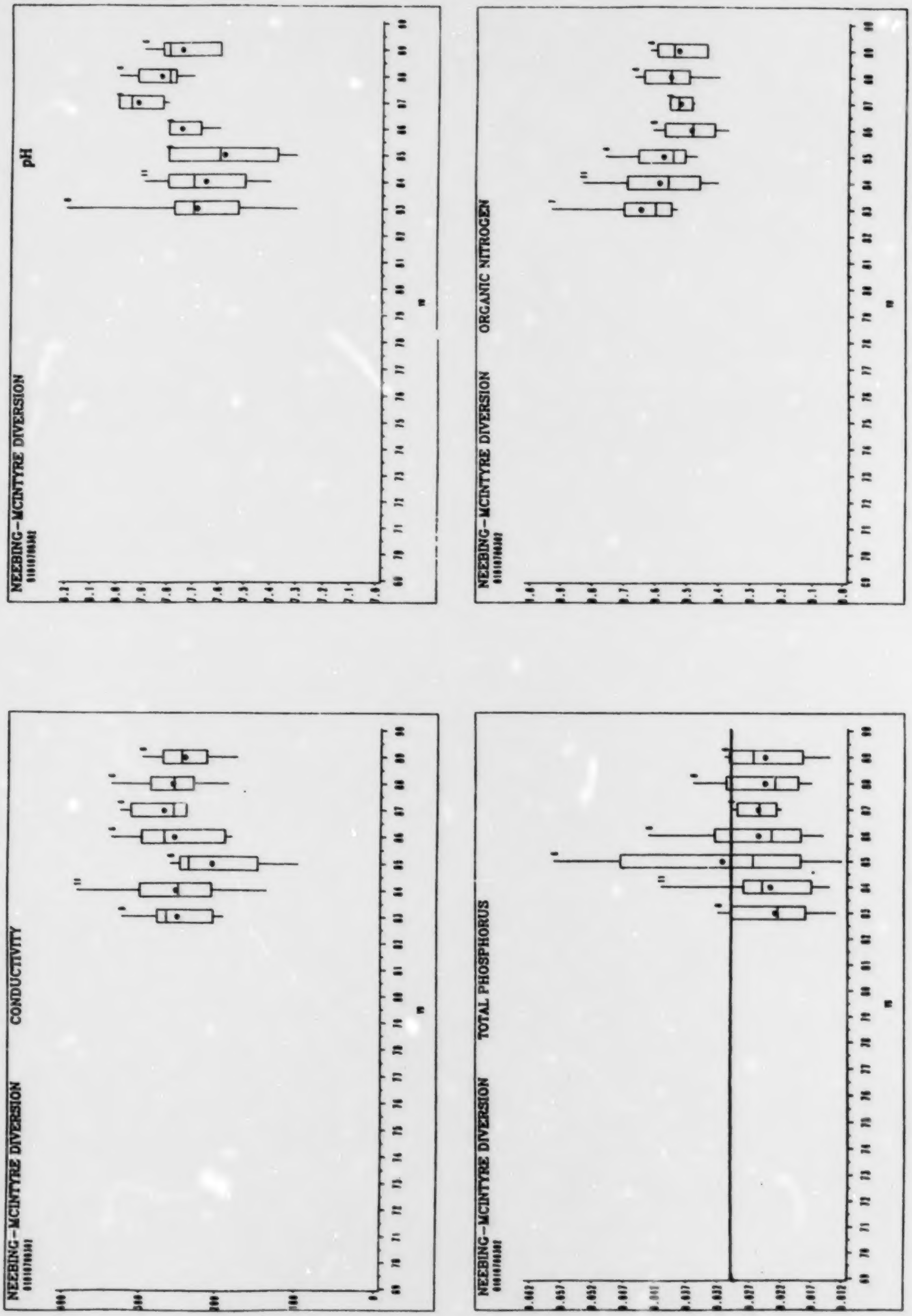


Fig. 73. Water quality in Neebing-McIntyre Diversion.

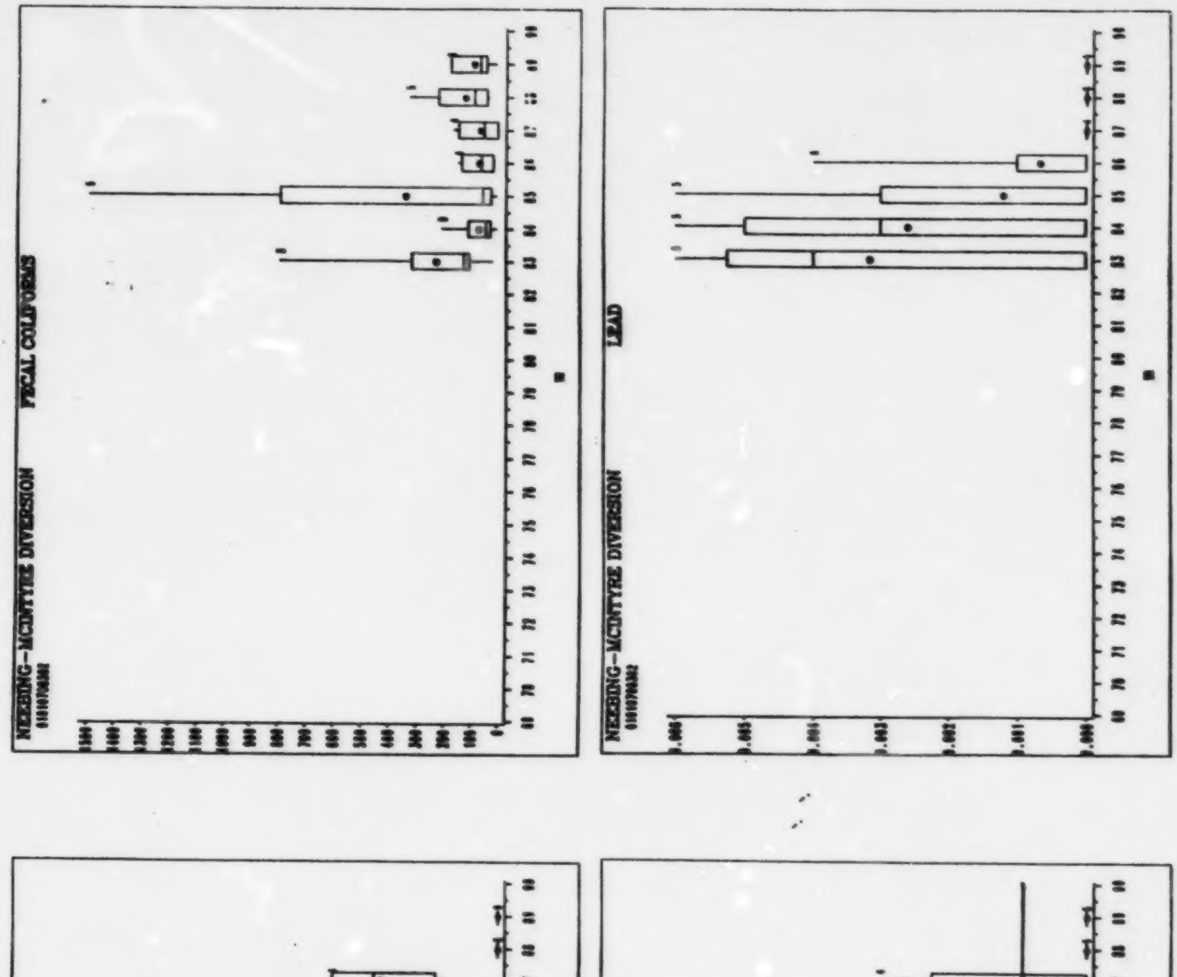


Fig. 74. Water quality in Neebing-McIntyre Diversion.

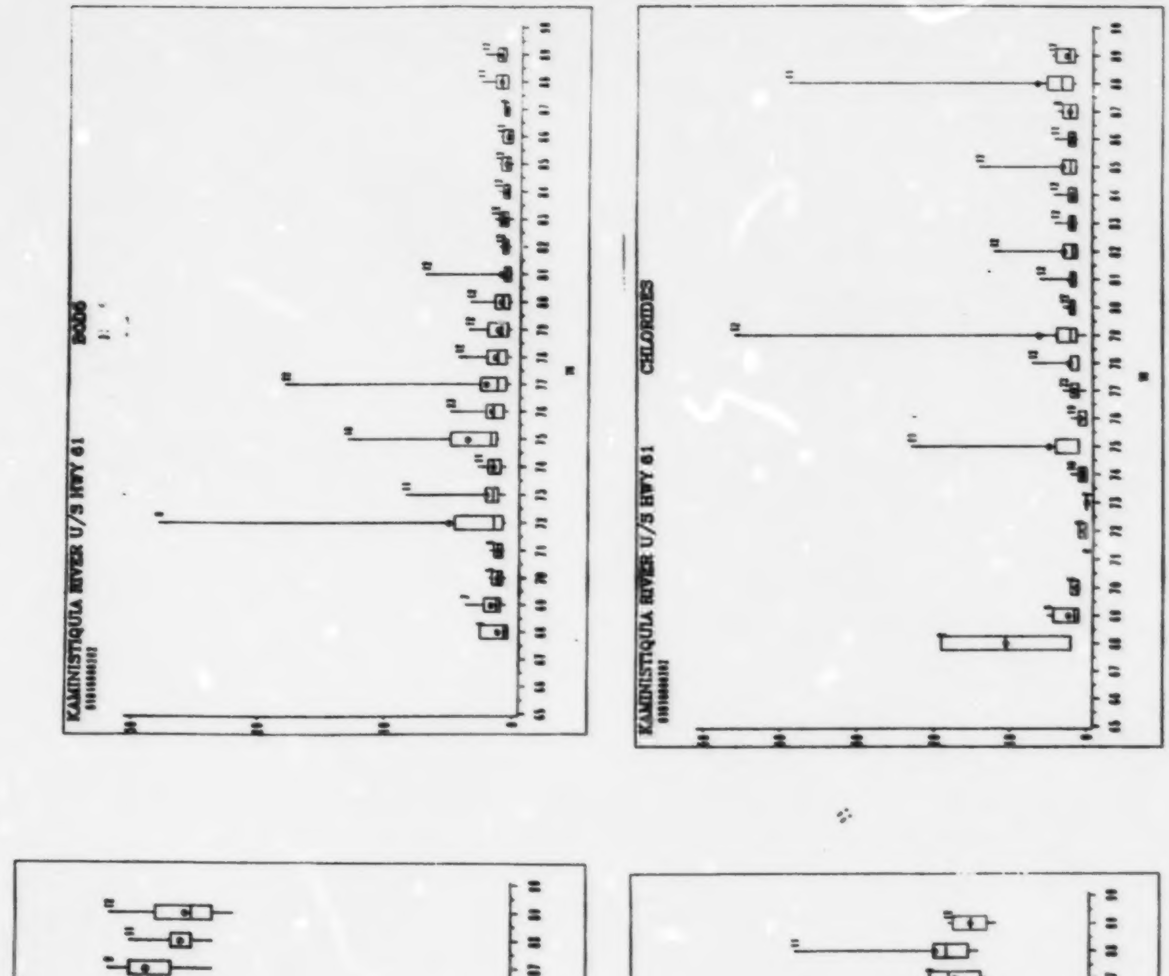


Fig. 75. Water quality in Kaministiquia River U/S Hwy. 61.

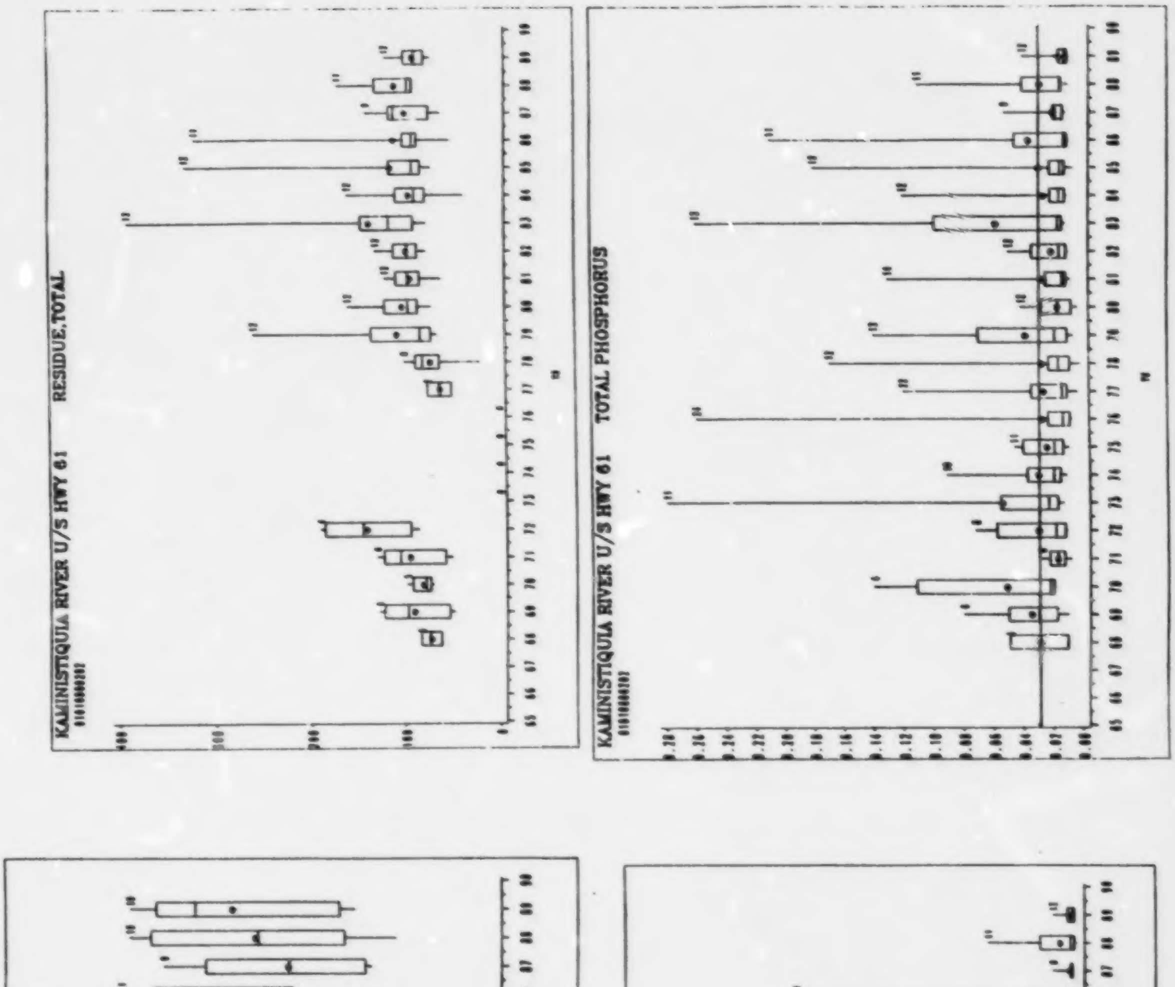


Fig. 76. Water quality in Kaministiquia River U/S Hwy. 61.

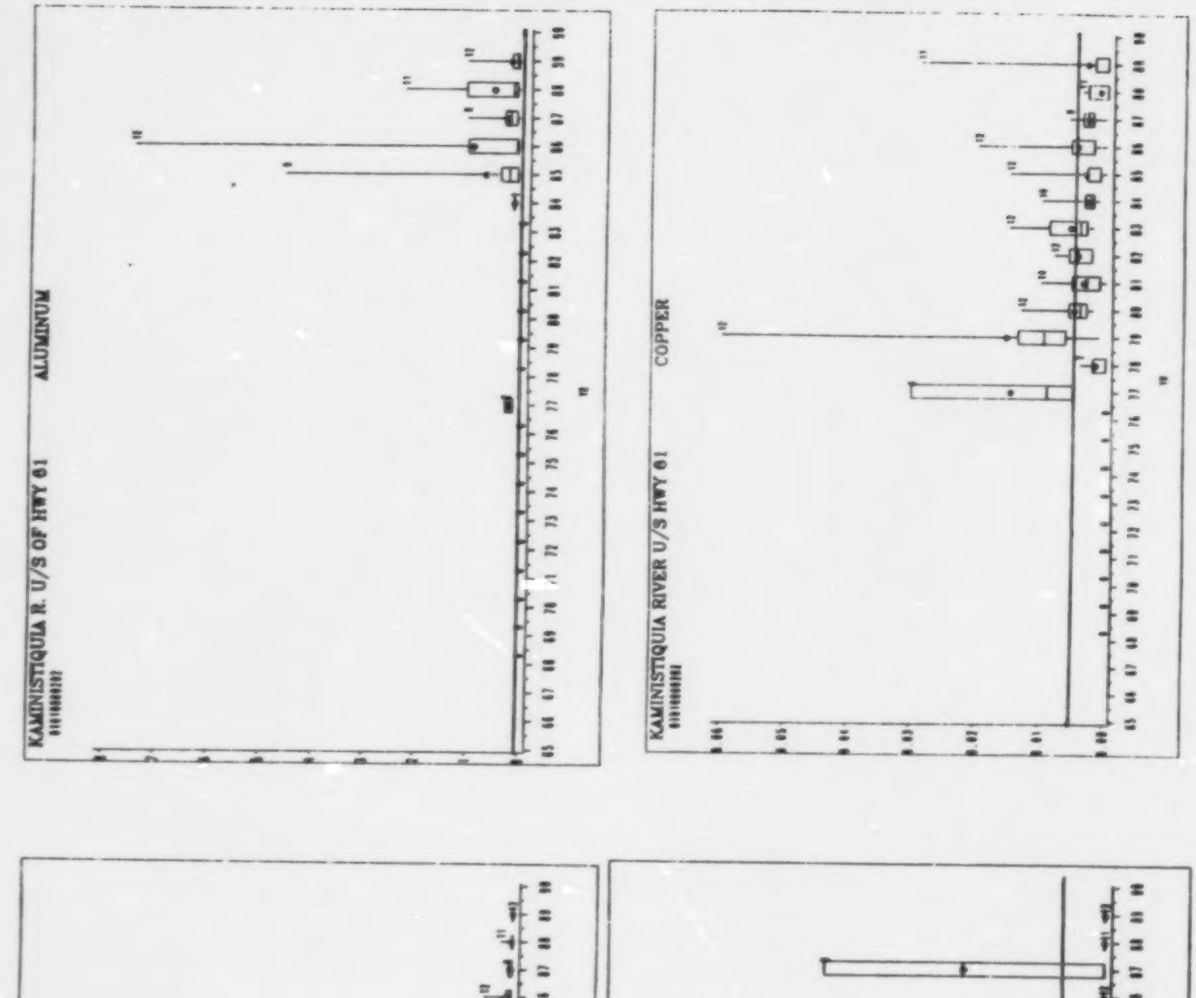


Fig. 77. Water quality in Kaministiquia River U/S Hwy. 61.

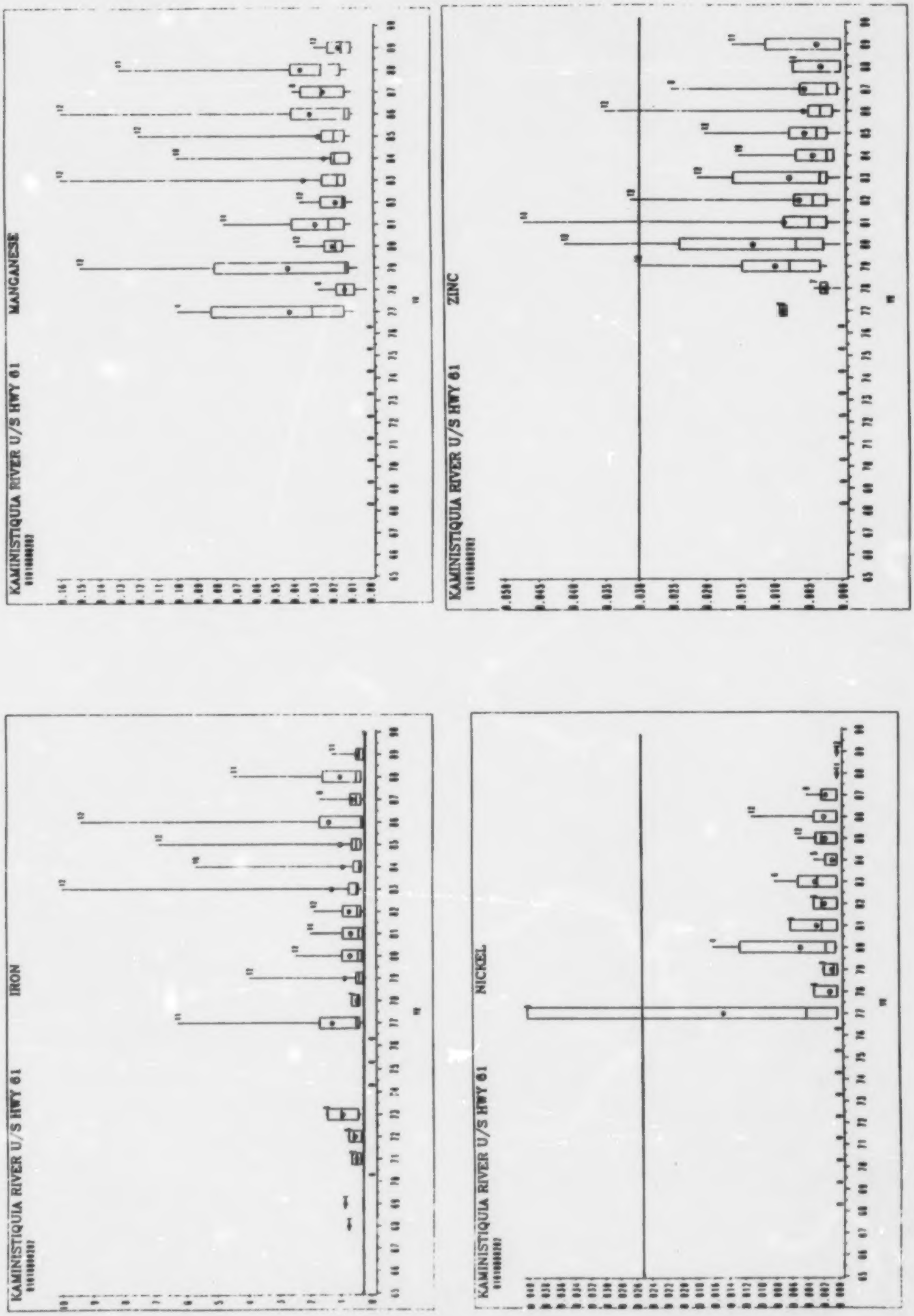


Fig. 78. Water quality in Kaministiquia River U/S Hwy. 61.

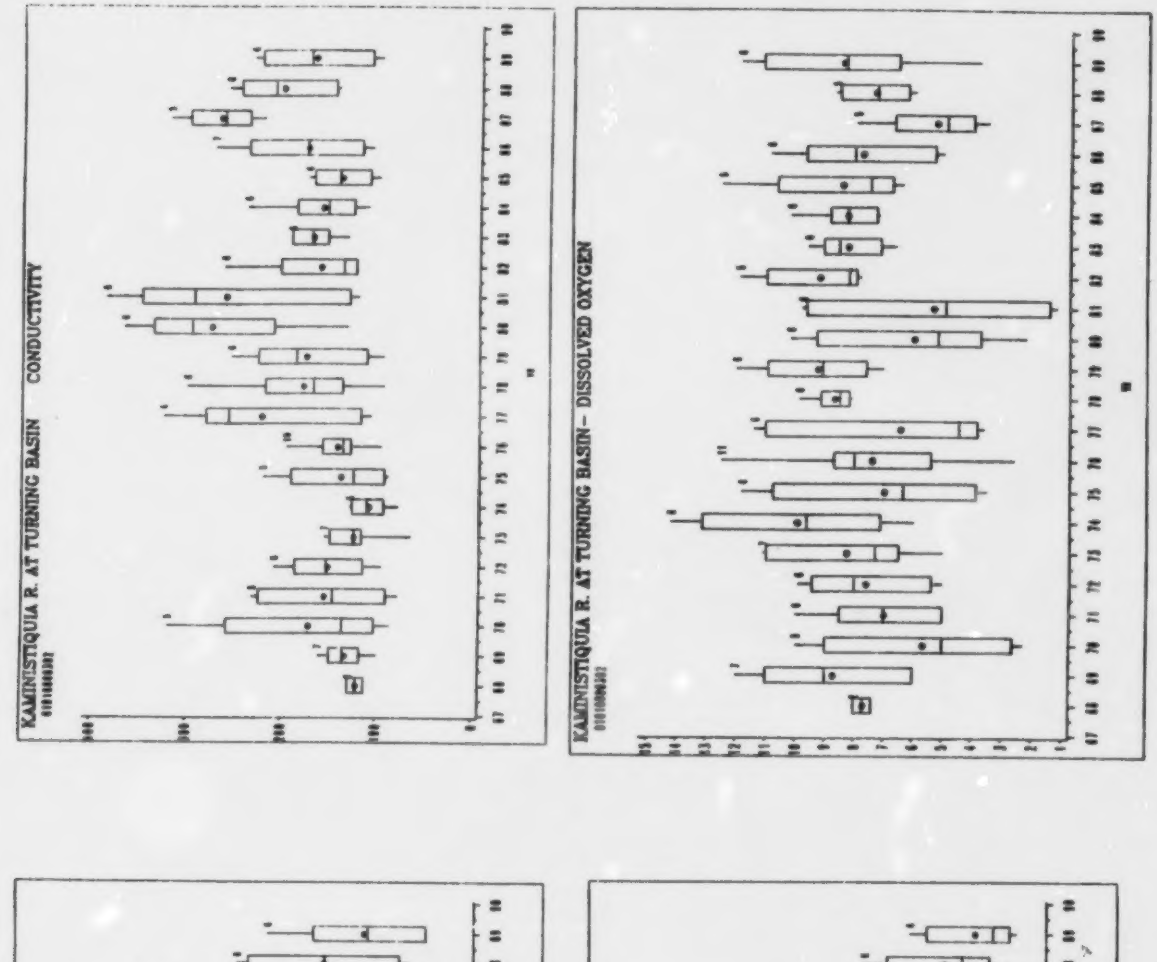


Fig. 79. Water quality in Kaministiquia River at Turning Basin.

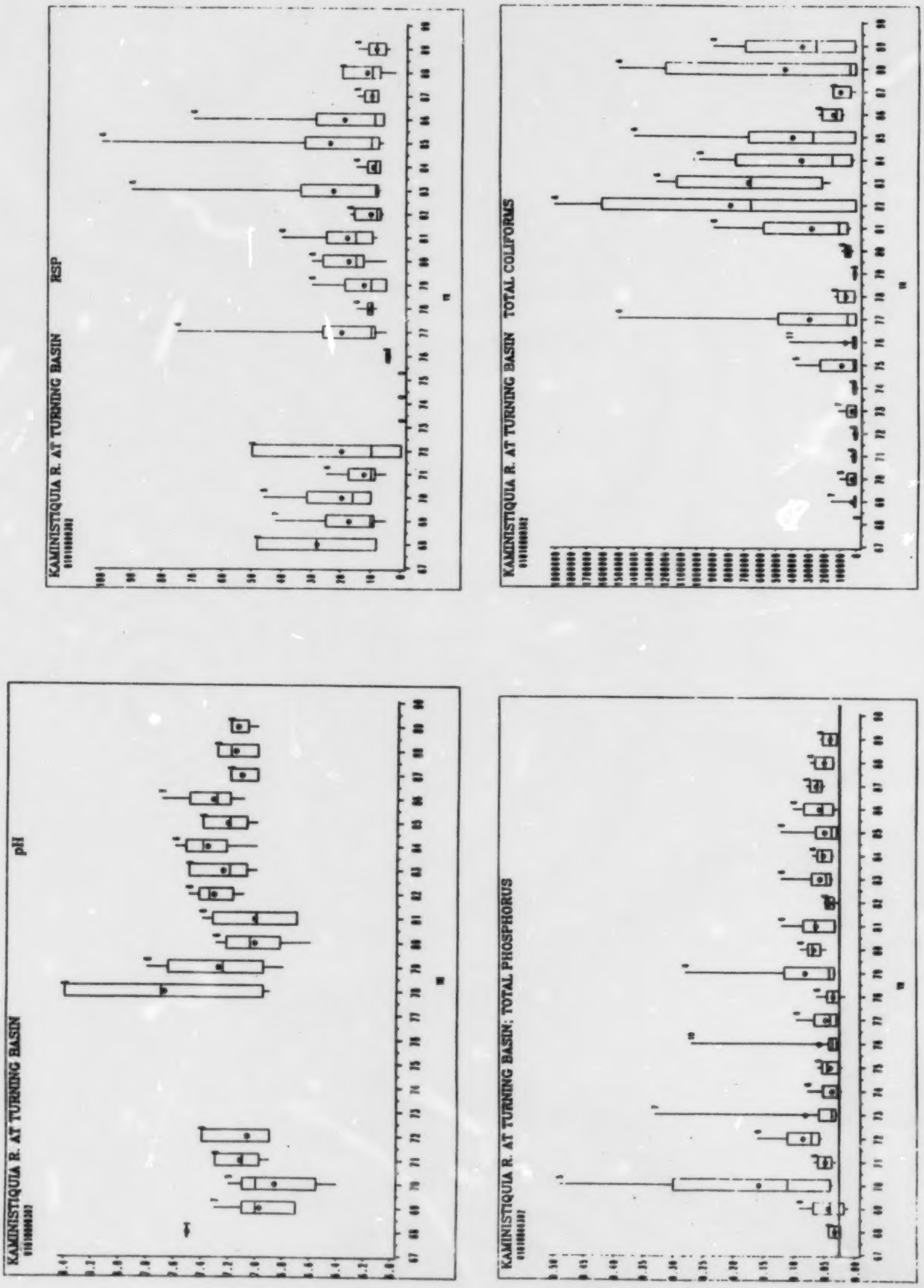


Fig. 80. Water quality in Kaministiquia River at Turning Basin.

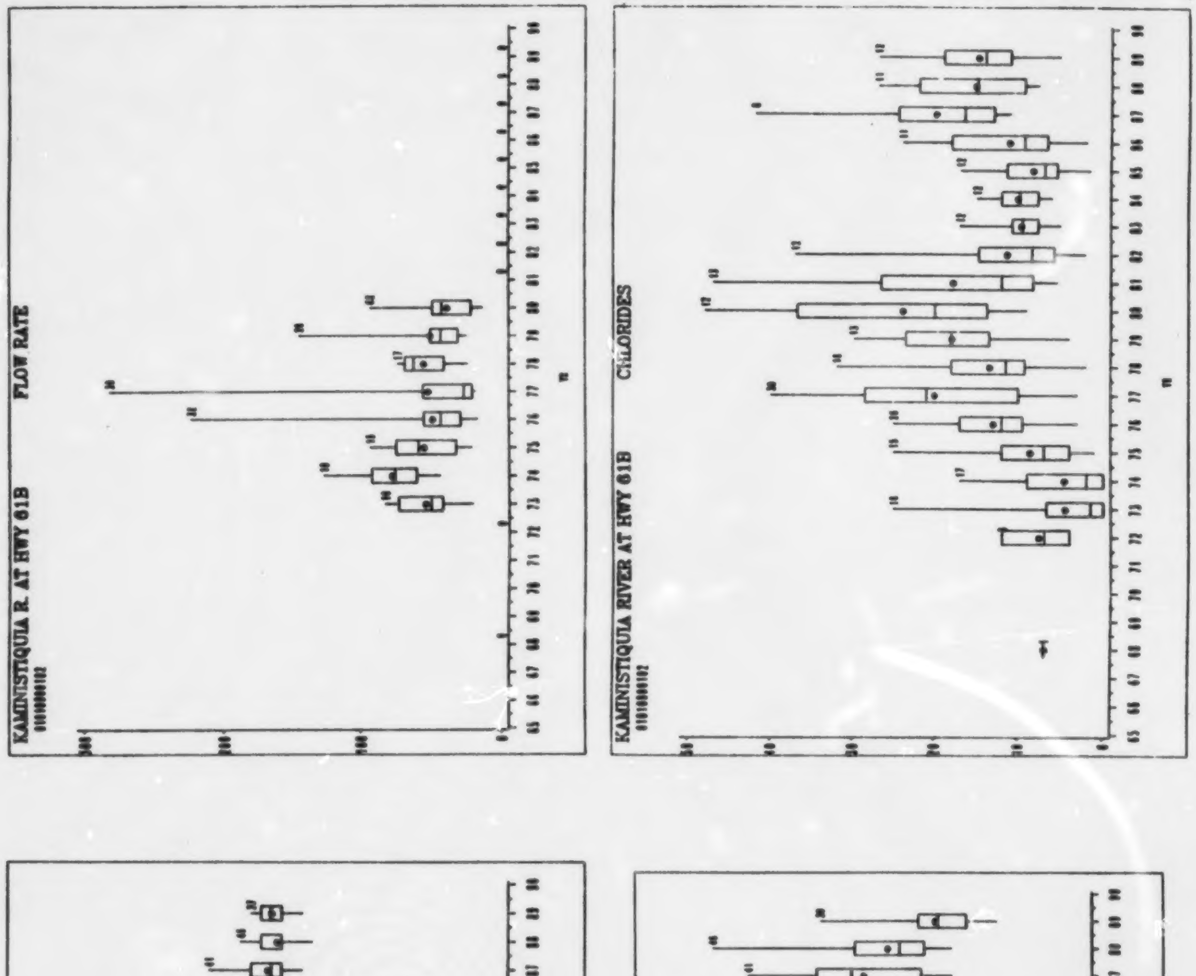


Fig. 81. Water quality in Kaministiquia River at Hwy. 61B.

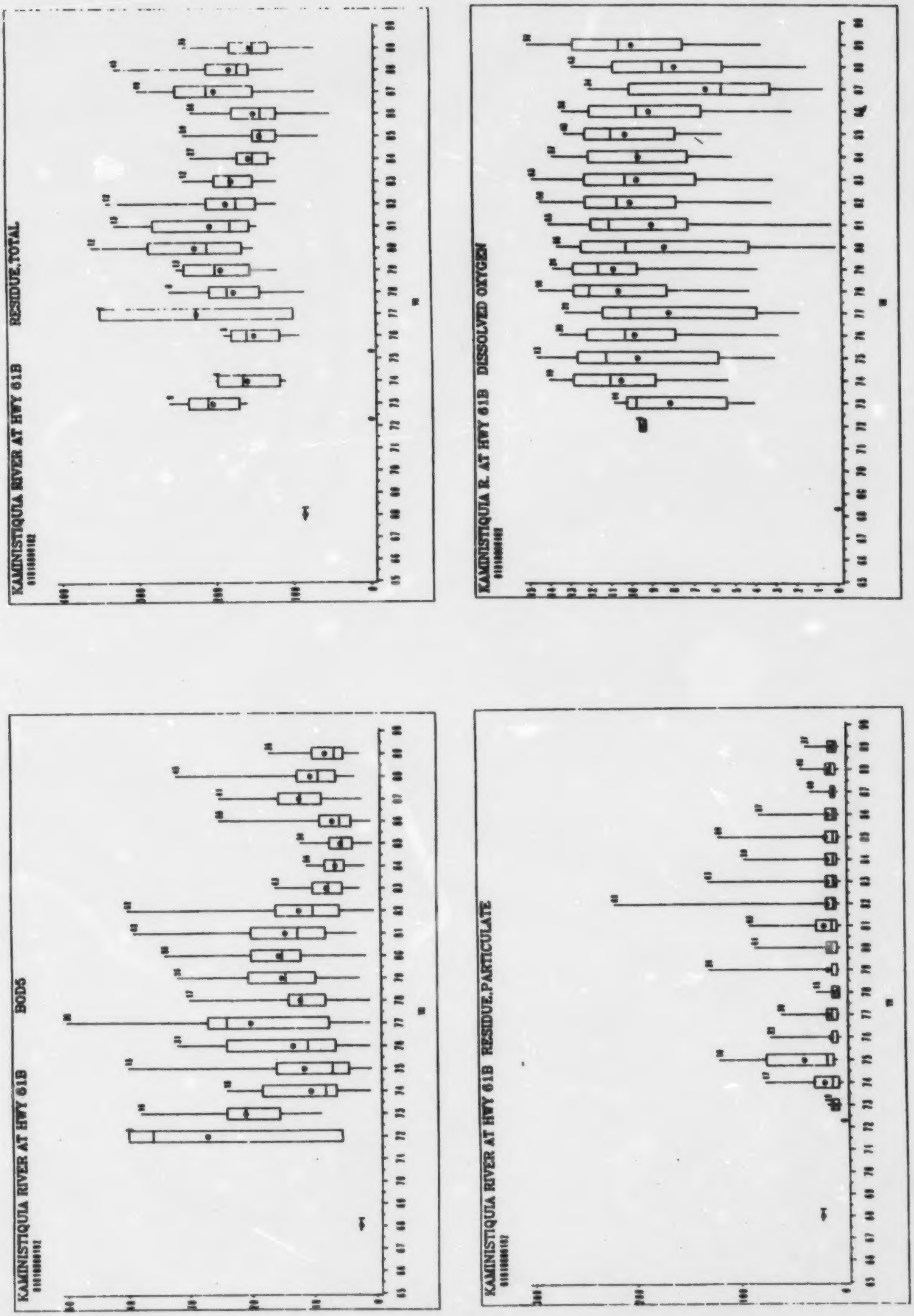


Fig. 82. Water quality in Kaministiquia River at Hwy. 61B.

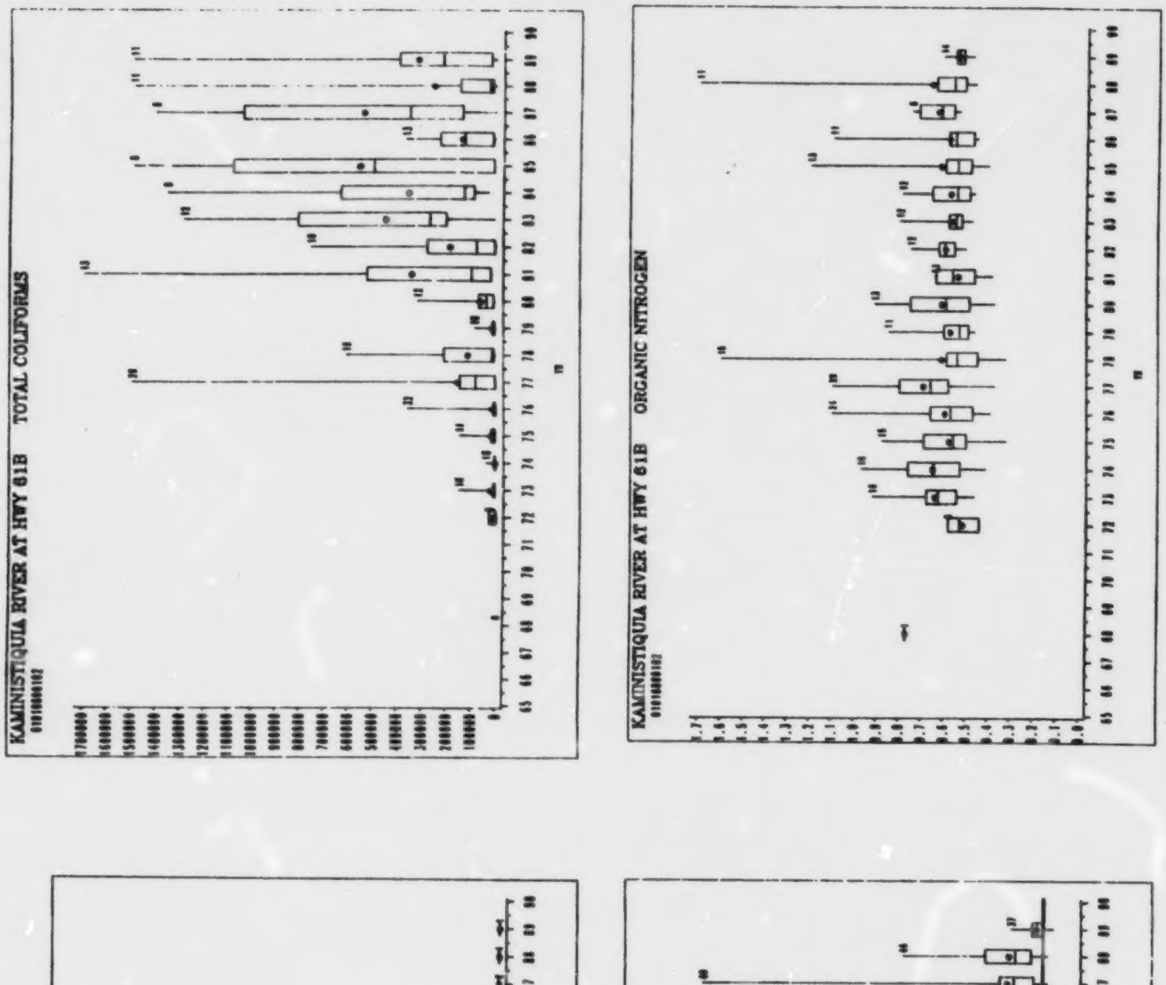


Fig. 83. Water quality in Kaministiquia River at Hwy. 61B.

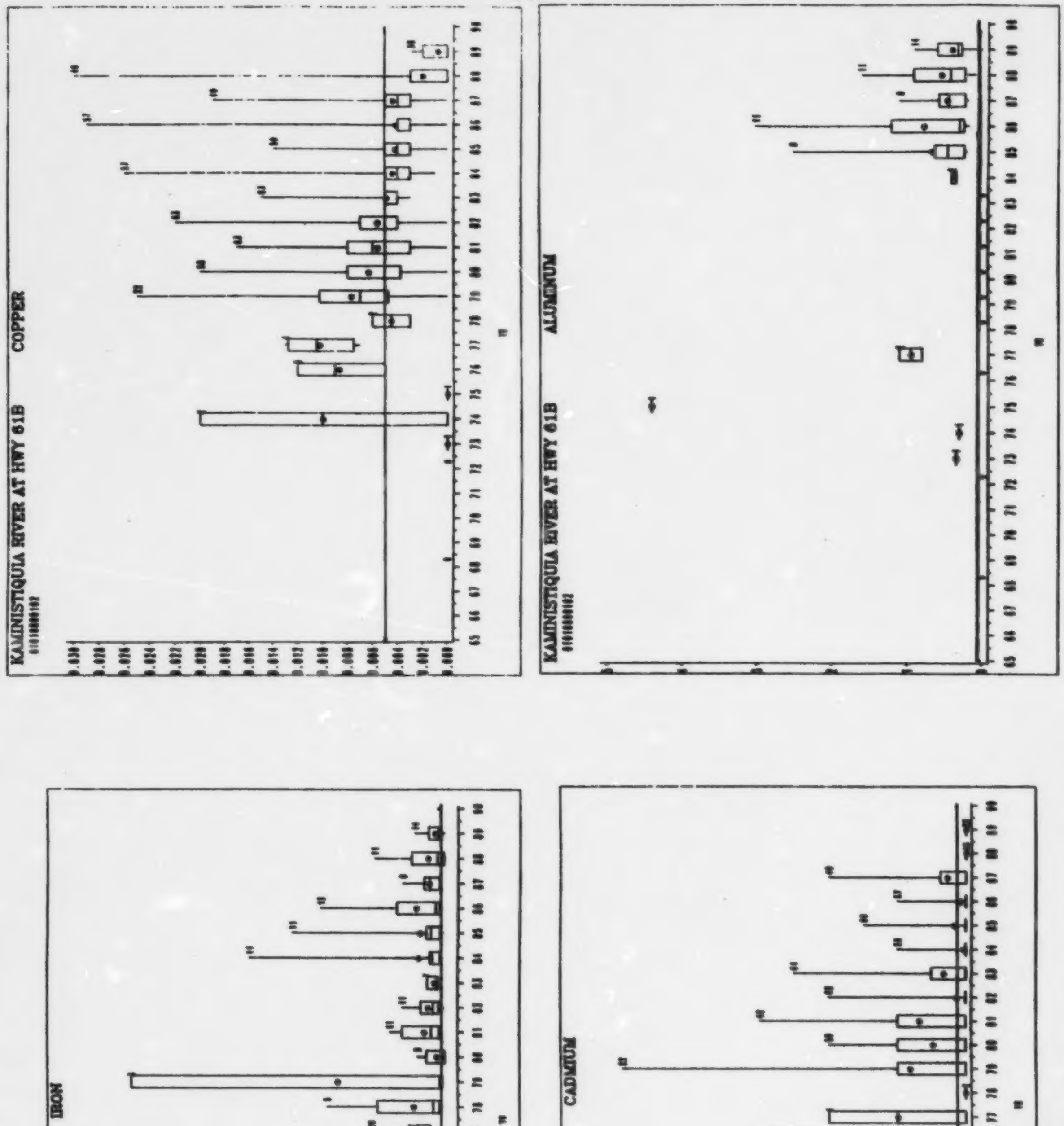


Fig. 84. Water quality in Kaministiquia River at Hwy. 61B.

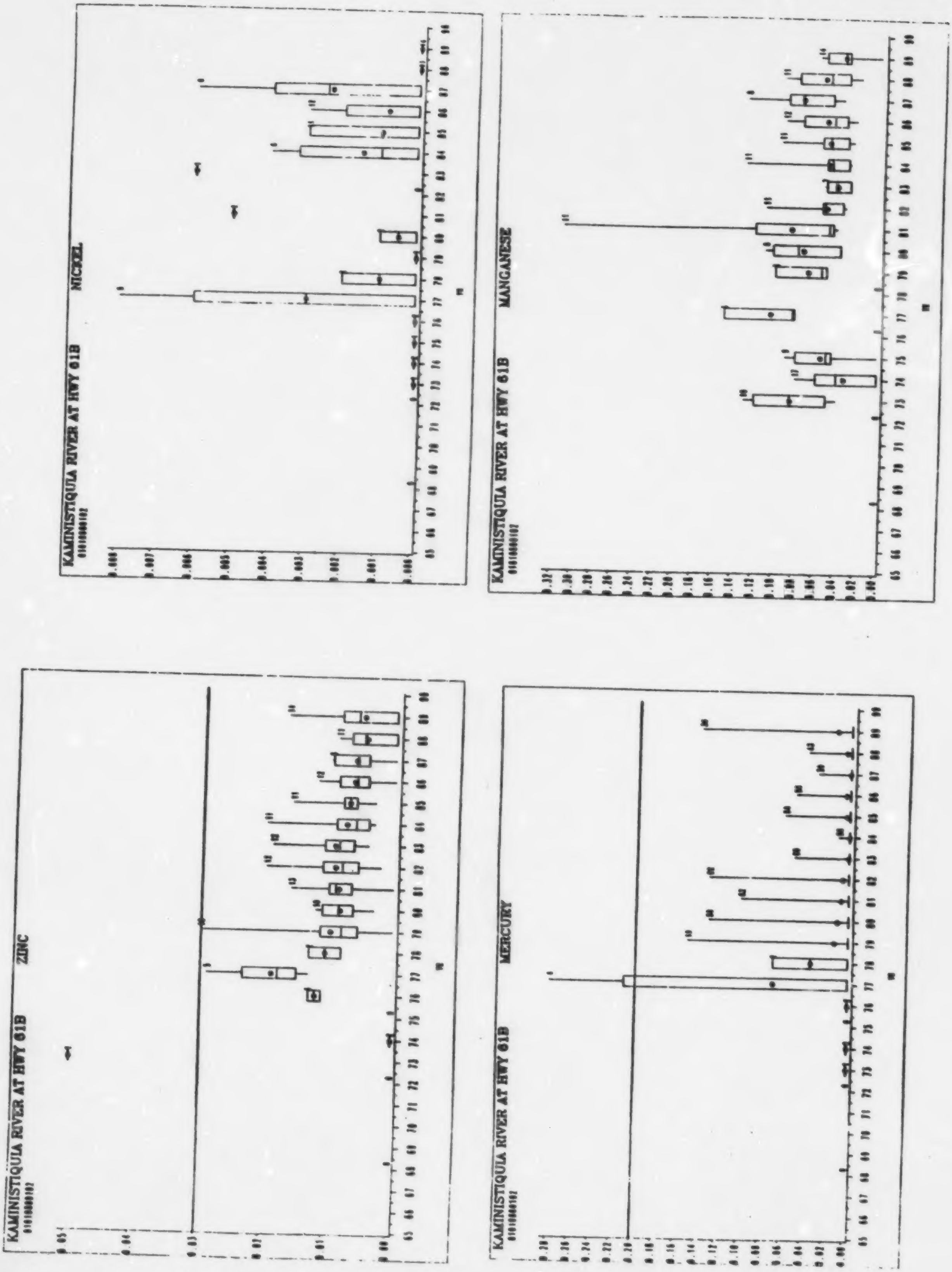


Fig. 85. Water quality in Kaministiquia River at Hwy. 61B.

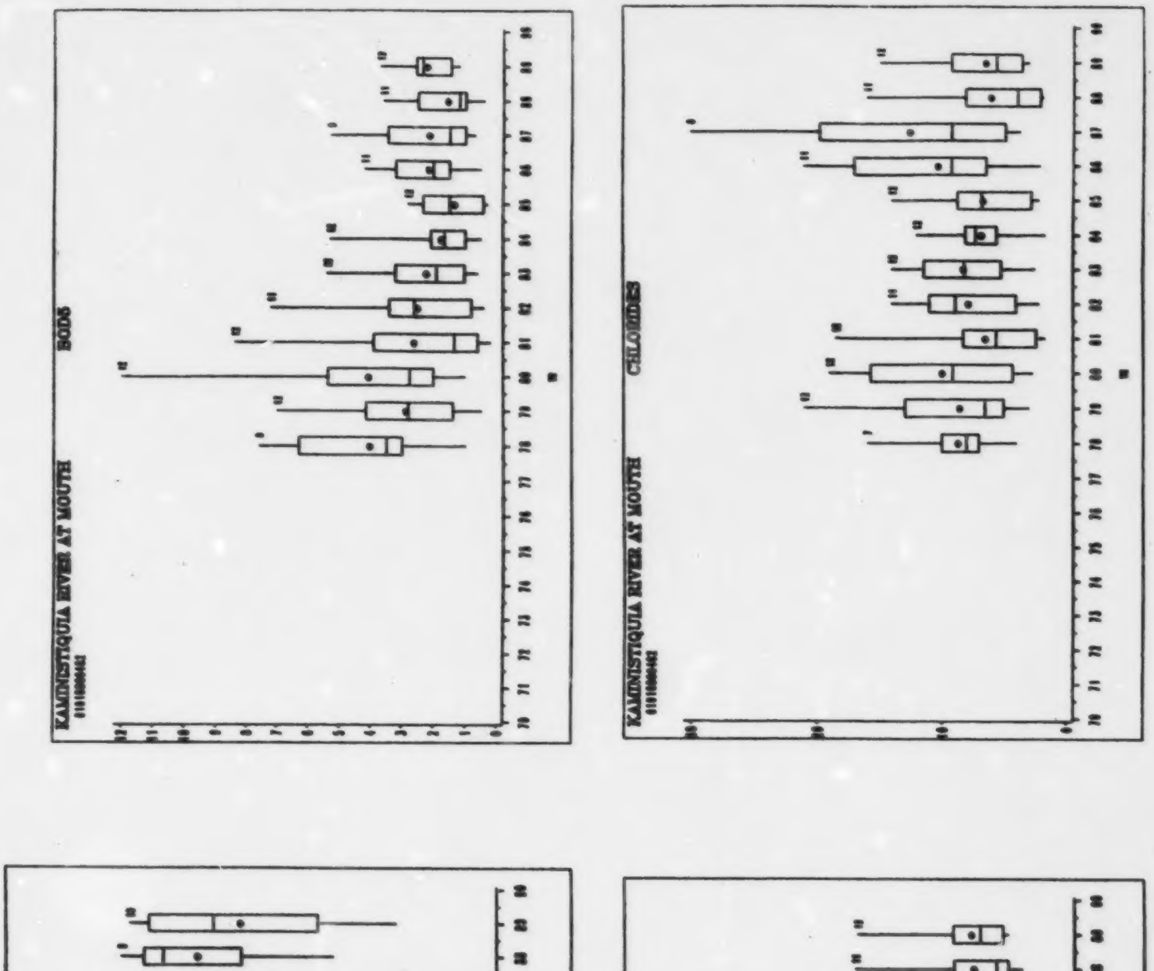


Fig. 86. Water quality in Kaministiquia River at Mission River.

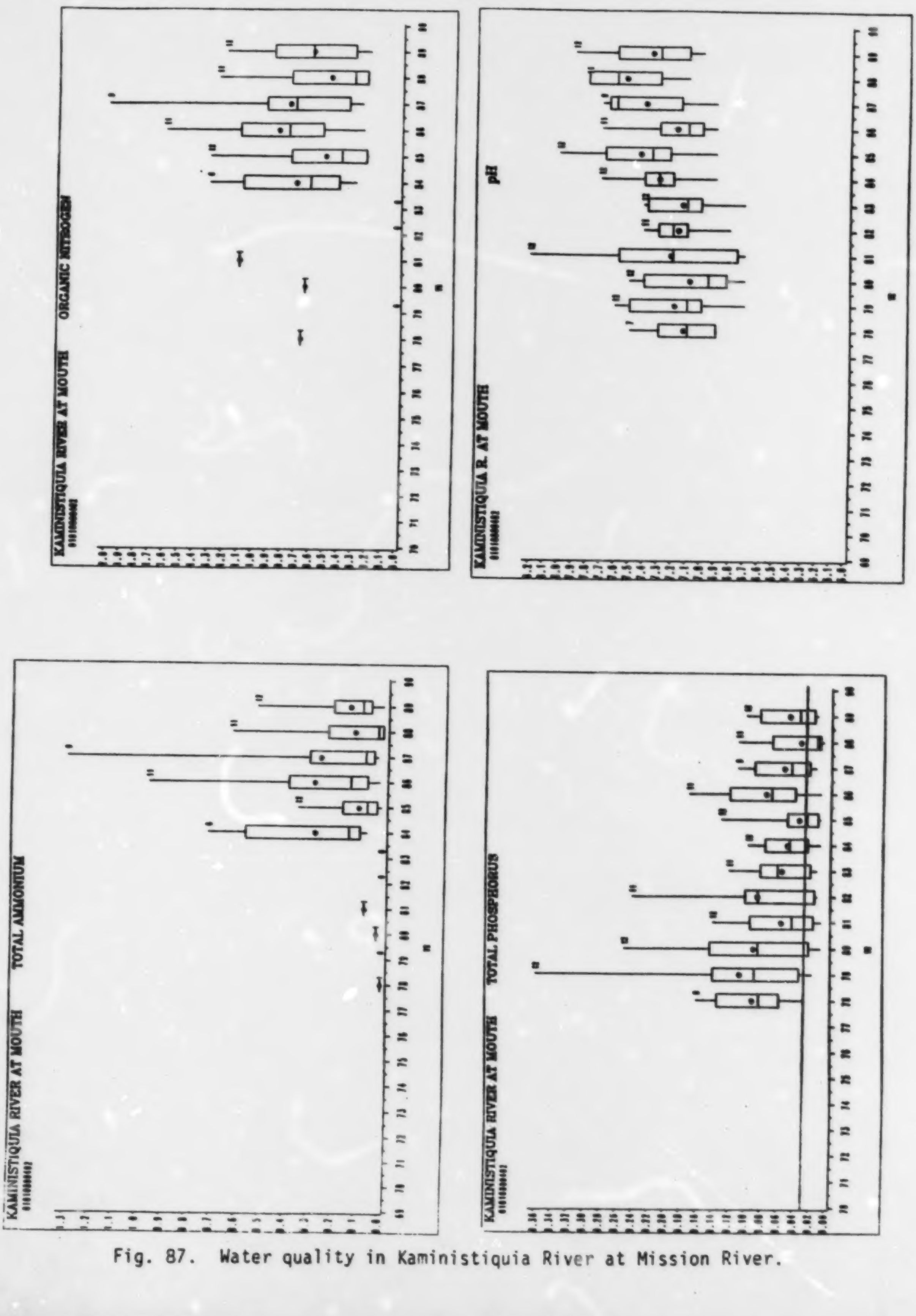
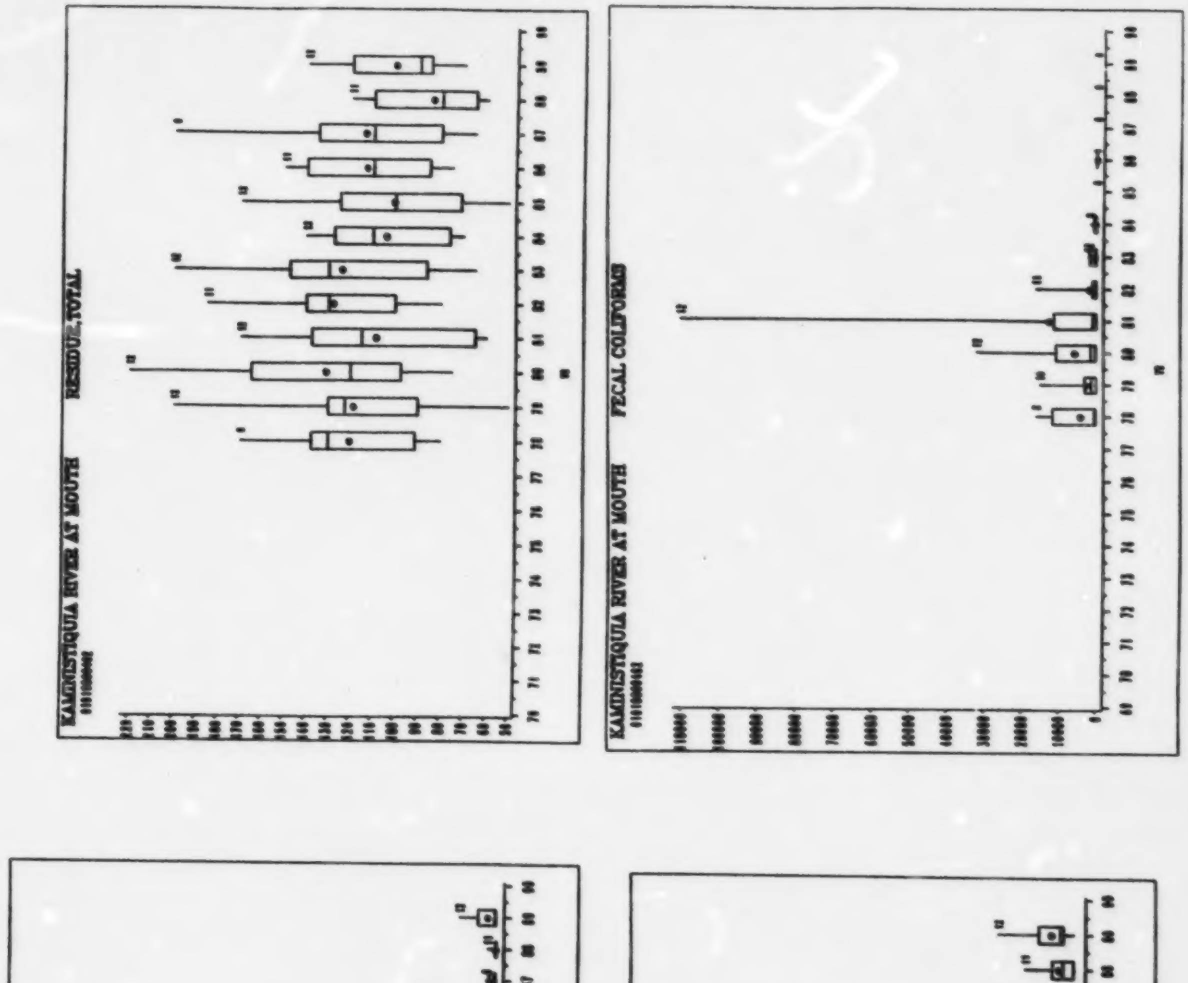


Fig. 87. Water quality in Kaministiquia River at Mission River.



KAMINISTIQUIA RIVER AT MOUTH RESIDUE,TOTAL

KAMINISTIQUIA RIVER AT MOUTH FECAL COLIFORMS

KAMINISTIQUIA RIVER AT MOUTH TOTAL COLIFORMS

KAMINISTIQUIA RIVER AT MOUTH RESIDUE,PARTICULATE

Fig. 88. Water quality in Kaministiquia River at Mission River.

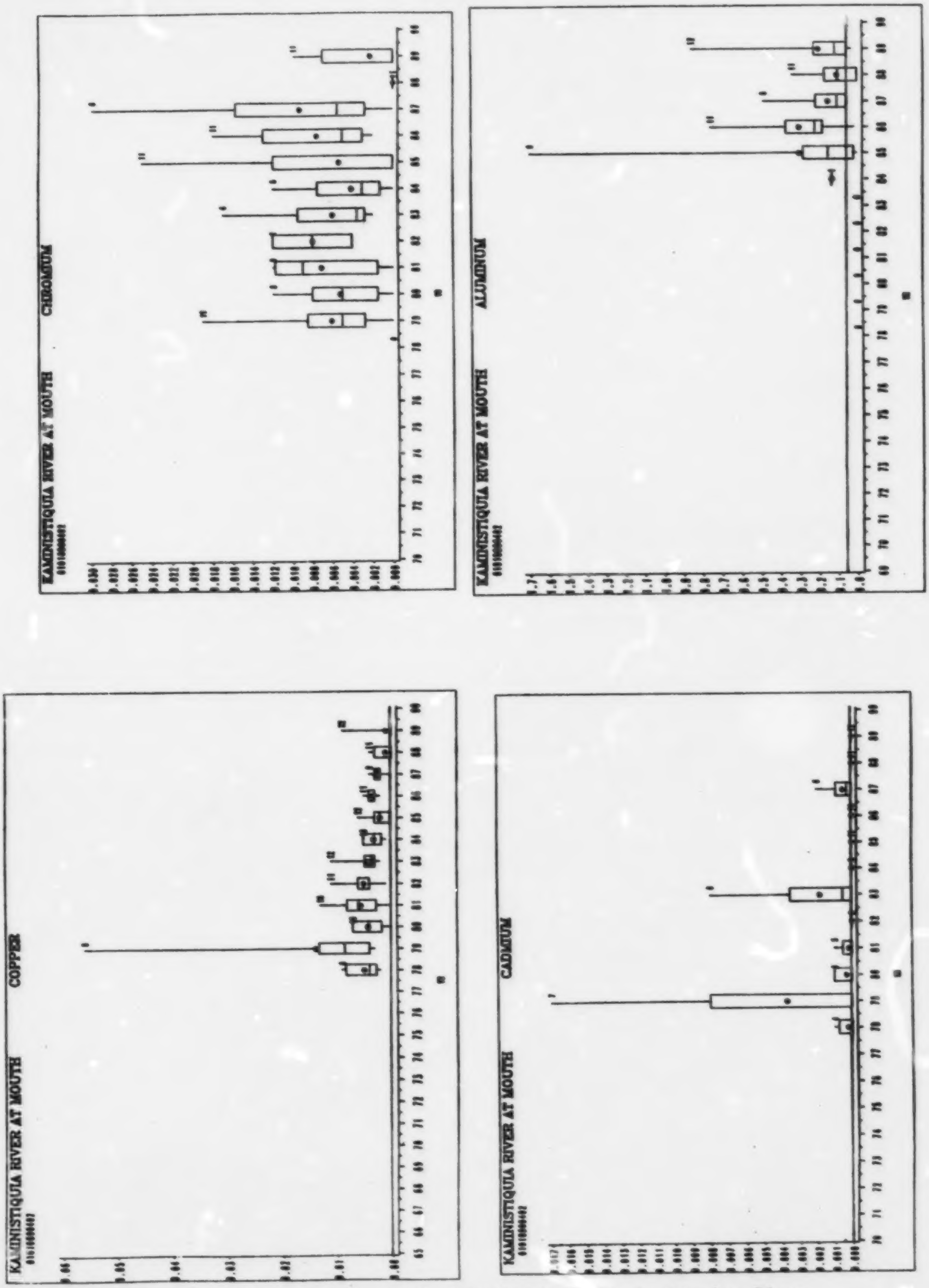


Fig. 89. Water quality in Kaministiquia River at Mission River.

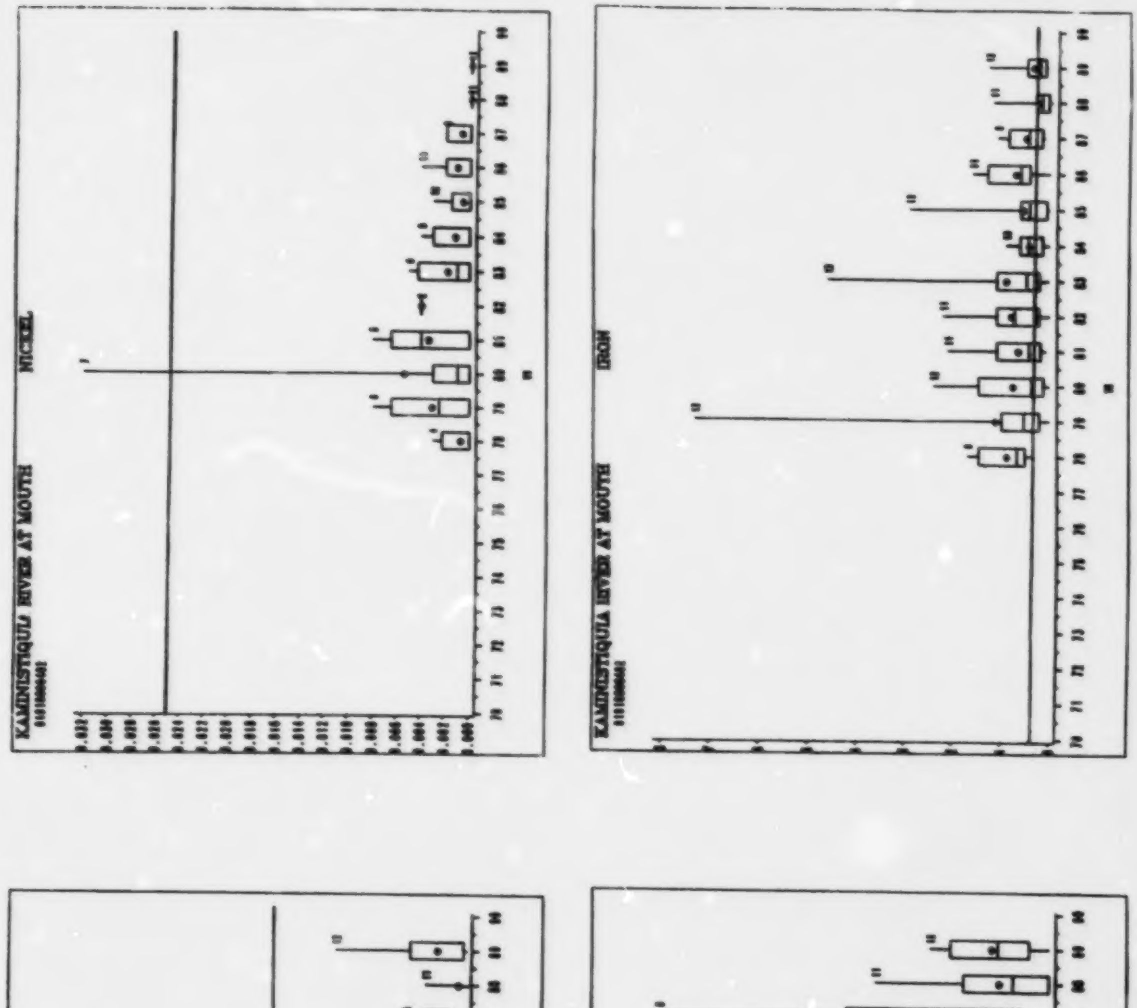


Fig. 90. Water quality in Kaministiquia River at Mission River.

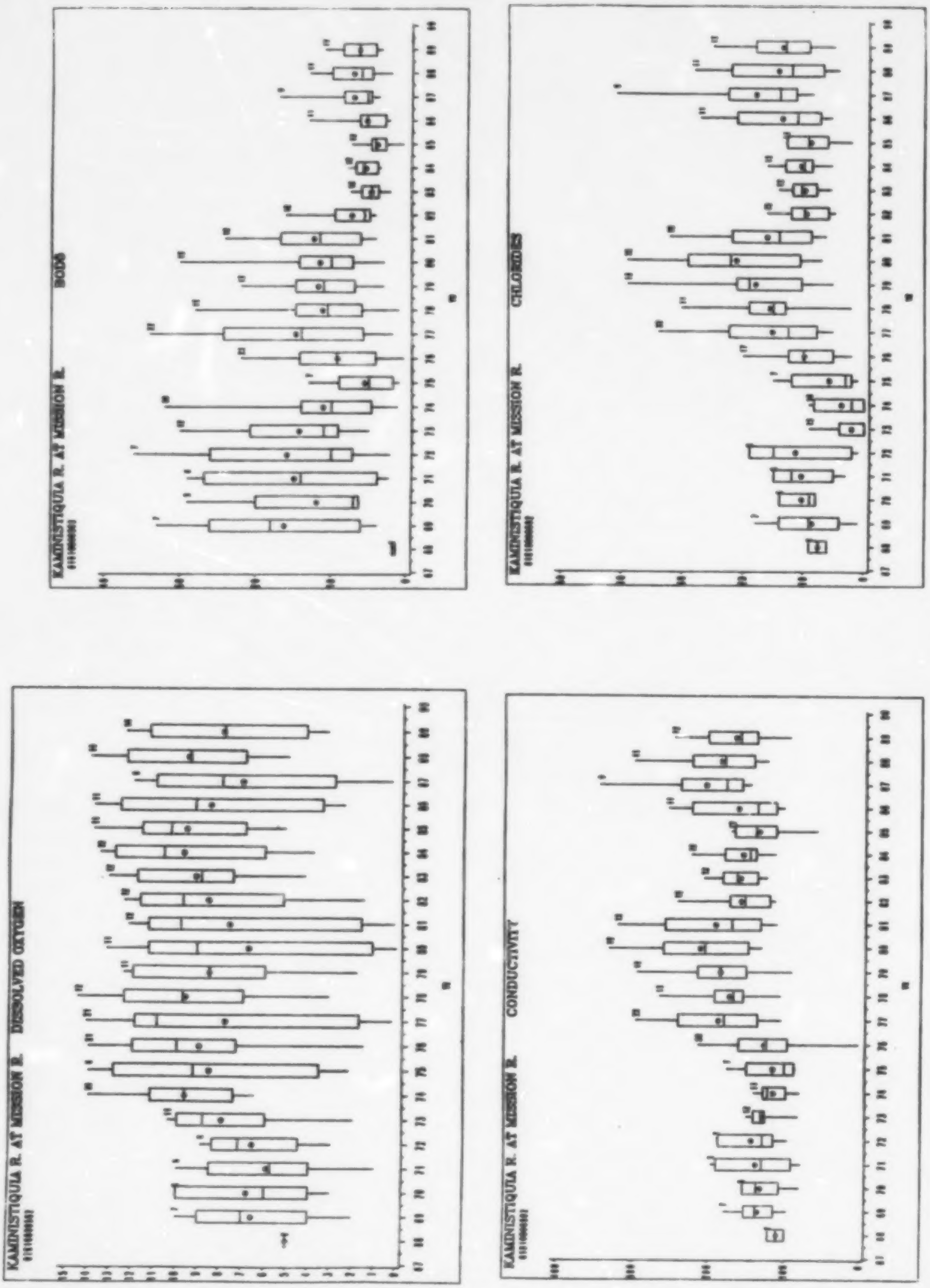


Fig. 91. Water quality in Kaministiquia River at mouth.

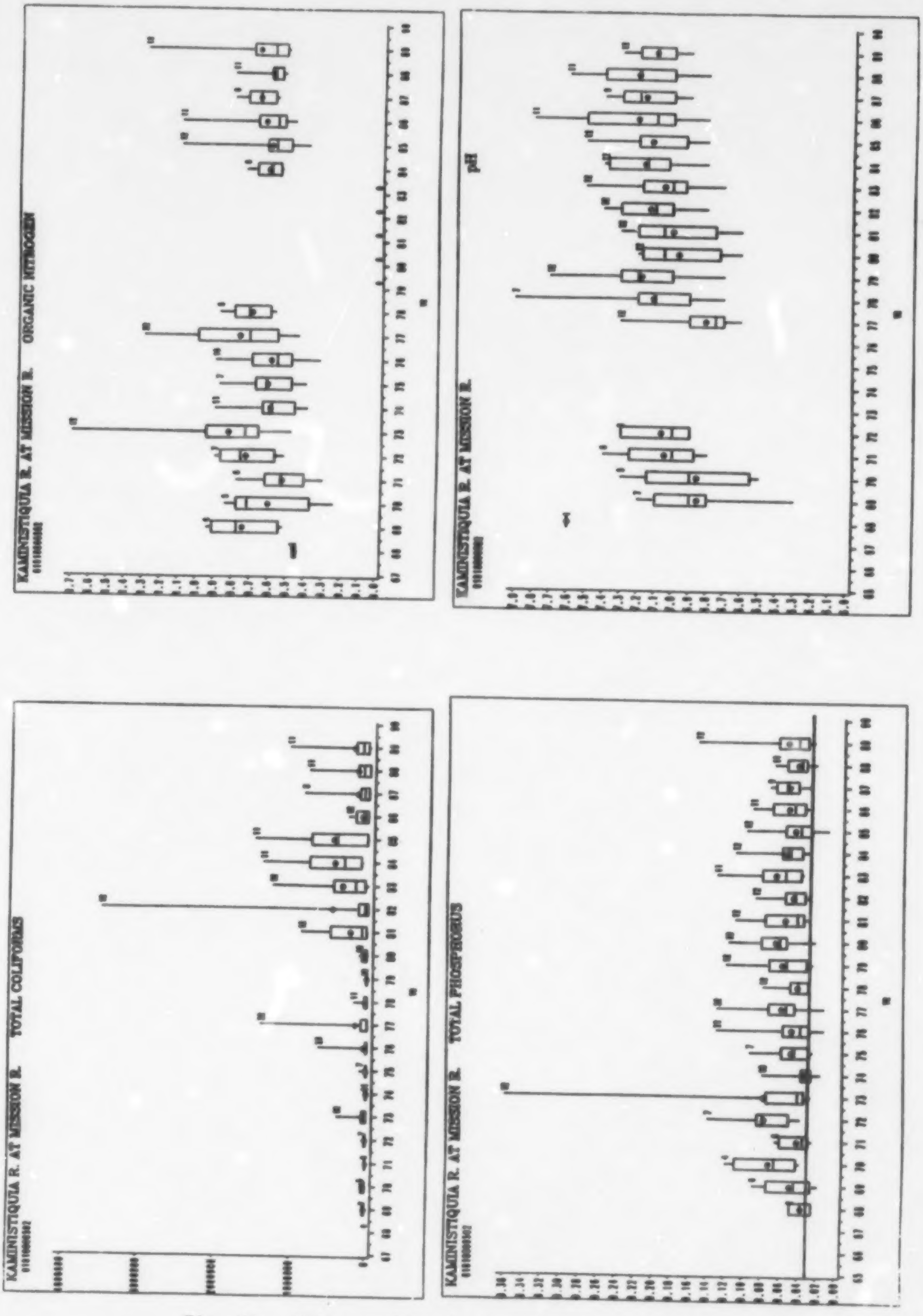


Fig. 92. Water quality in Kaministiquia River at mouth.

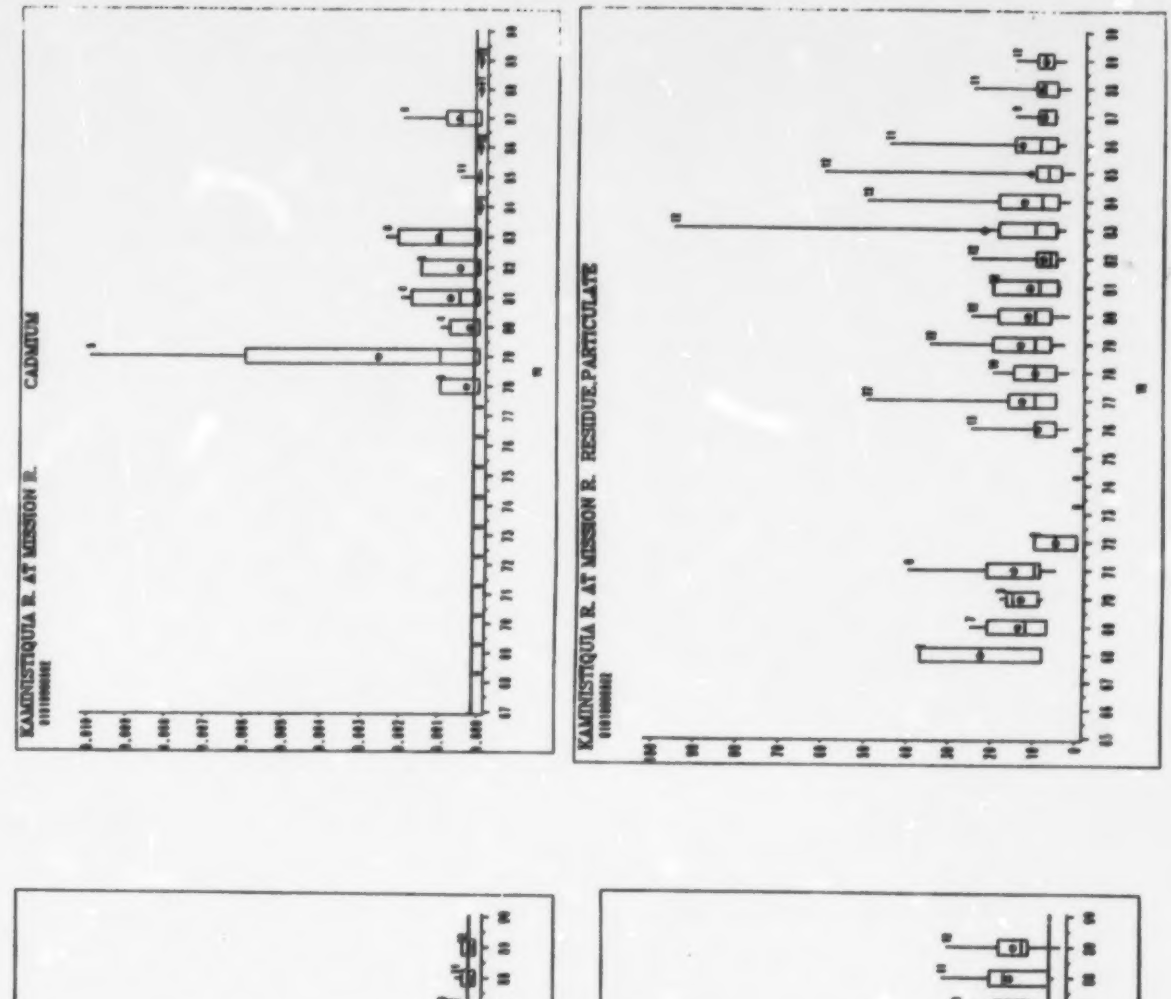


Fig. 93. Water quality in Kaministiquia River at mouth.

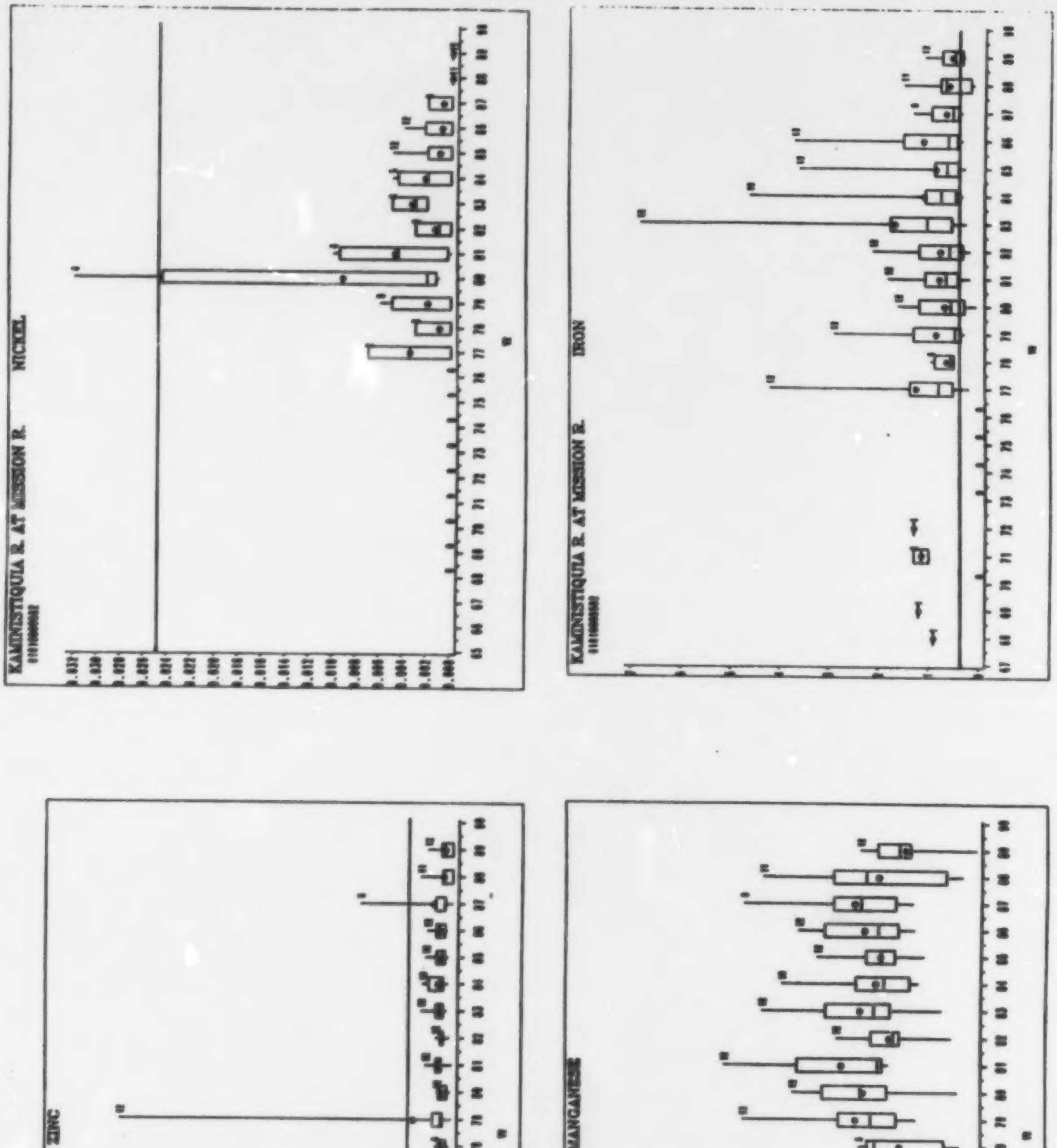


Fig. 94. Water quality in Kaministiquia River at mouth.

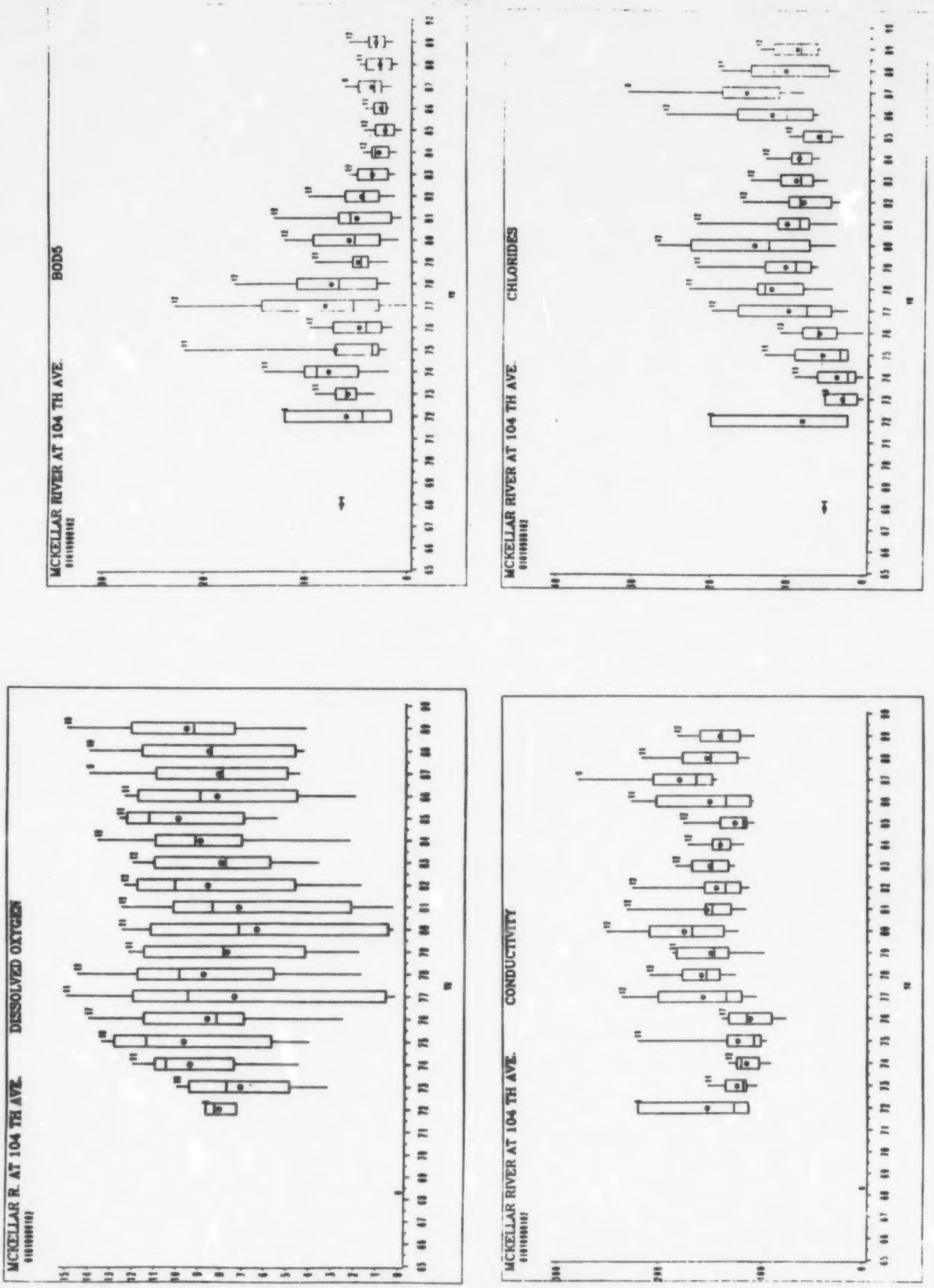


Fig. 95. Water quality in McKellar River at 104th Avenue.

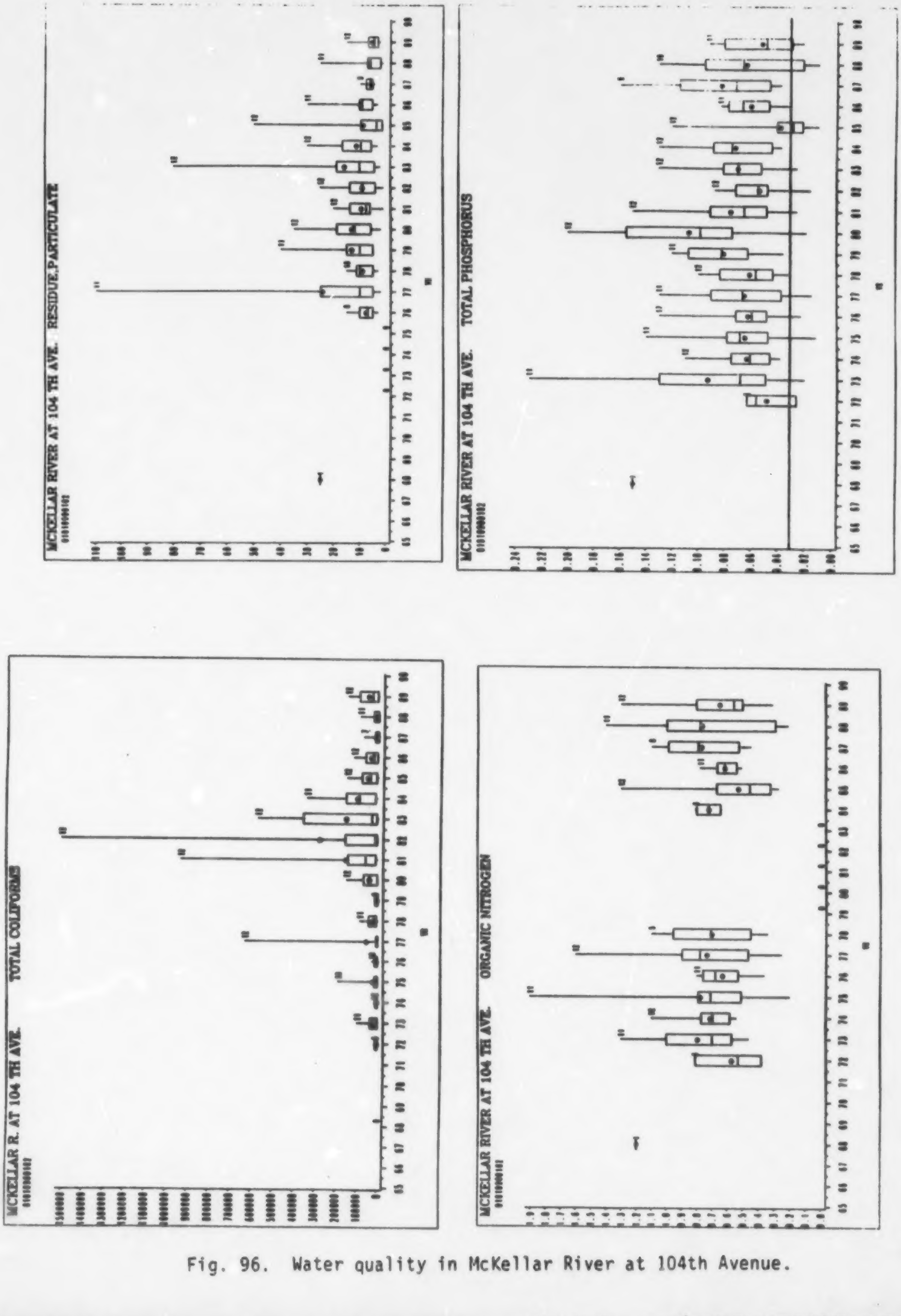


Fig. 96. Water quality in McKellar River at 104th Avenue.

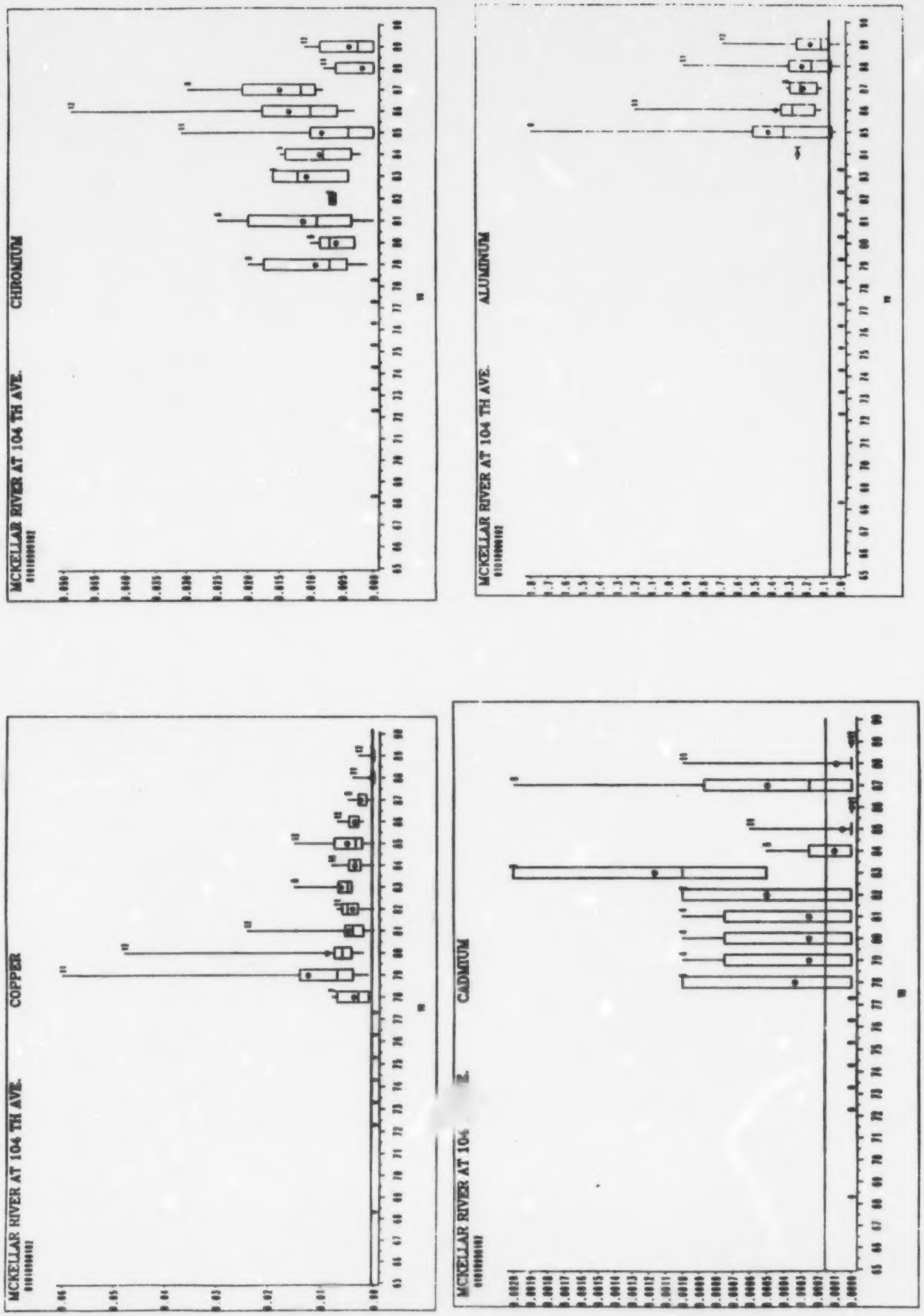


Fig. 97. Water quality in McKellar River at 104th Avenue.

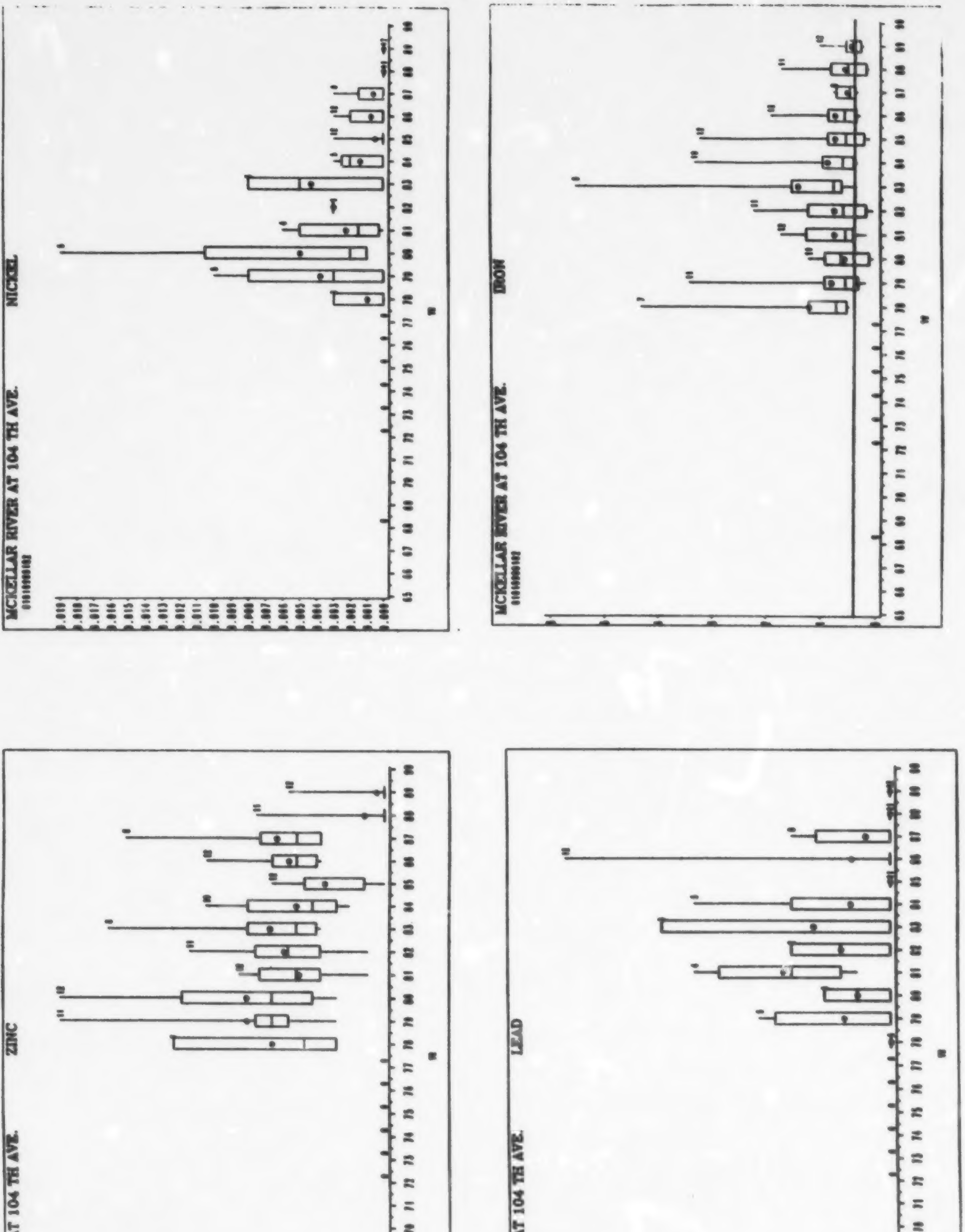


Fig. 98. Water quality in McKellar River at 104th Avenue.

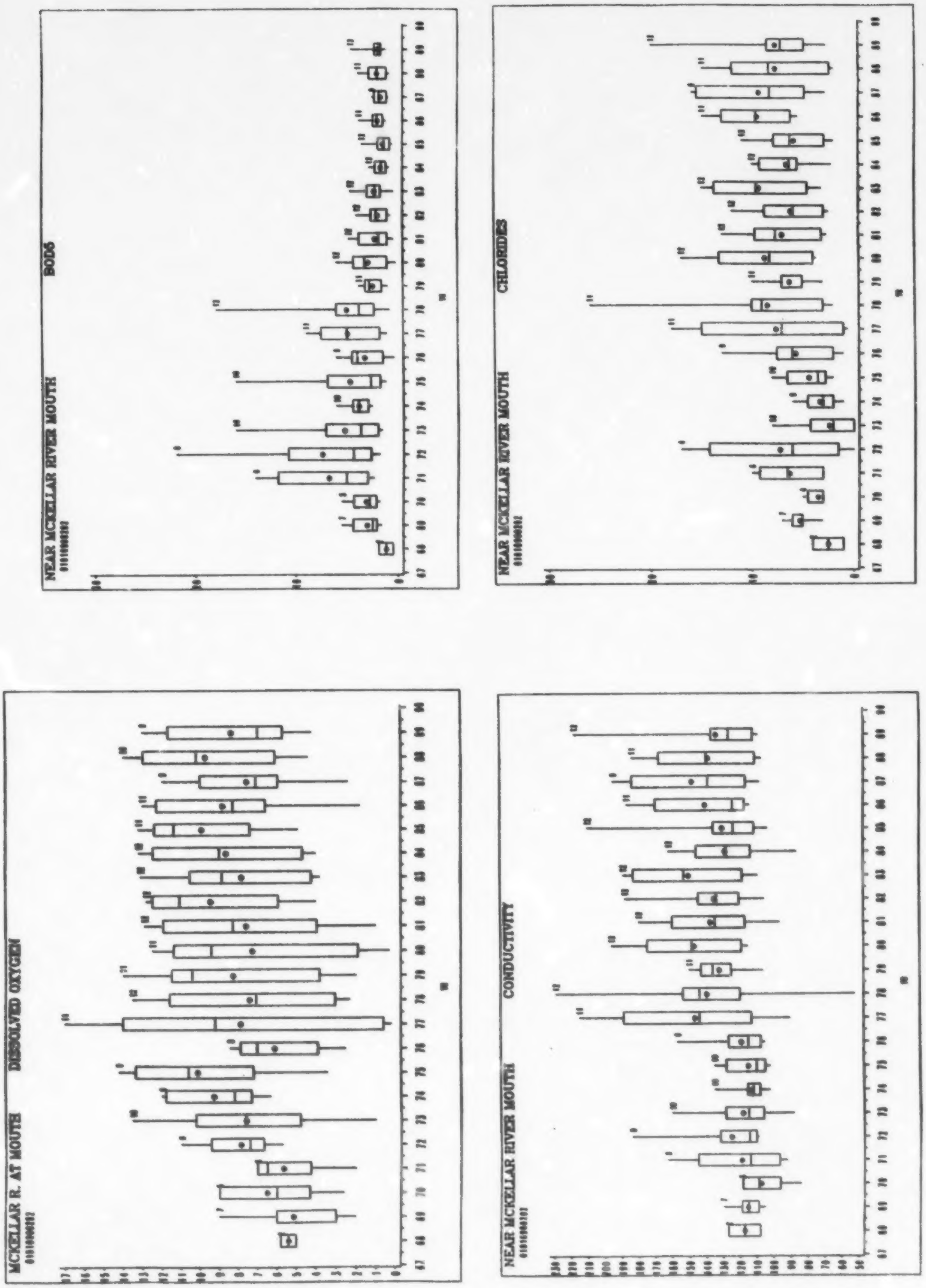


Fig. 99. Water quality in McKellar River at mouth.

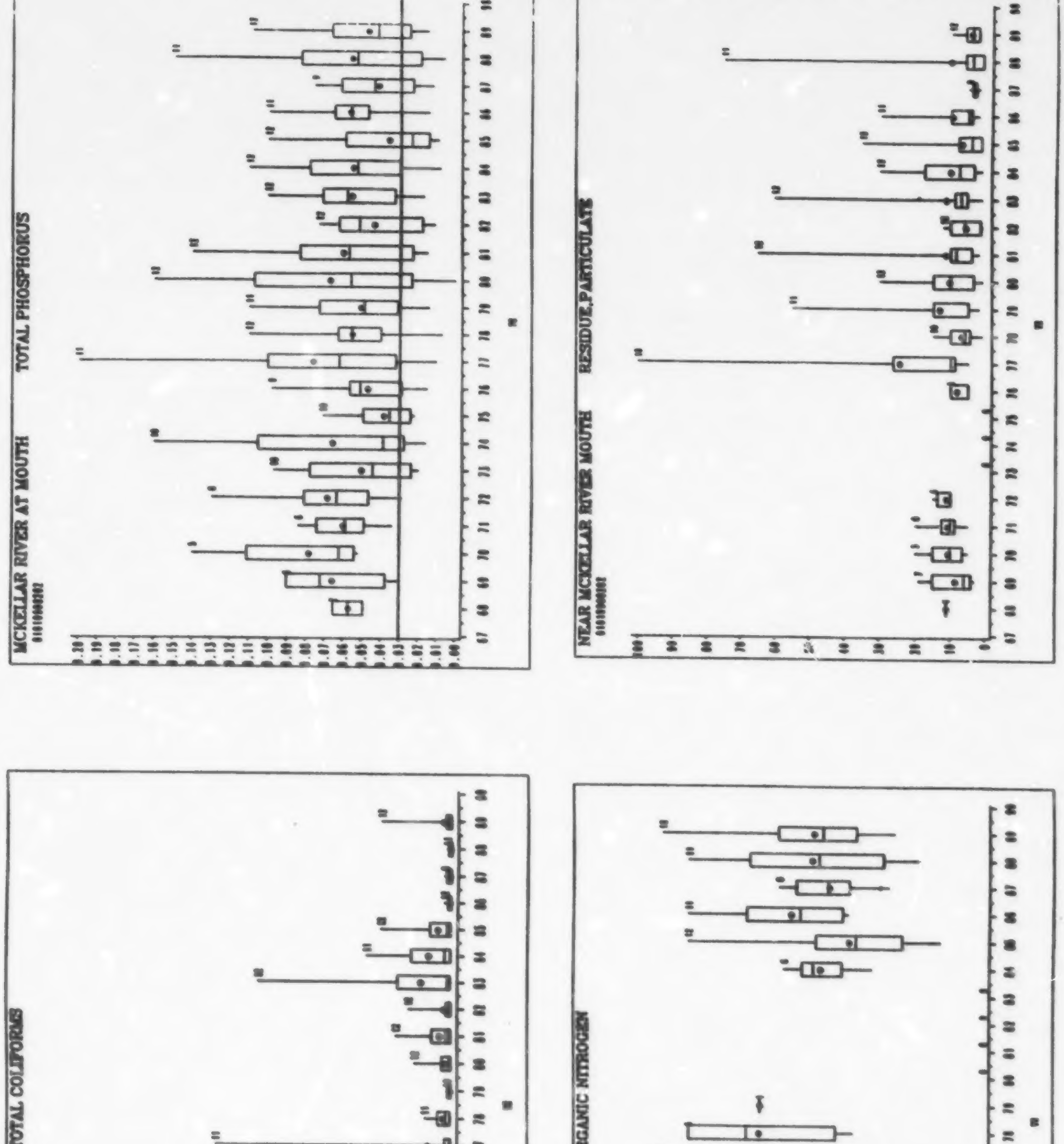


Fig. 100. Water quality in McKellar River at mouth.

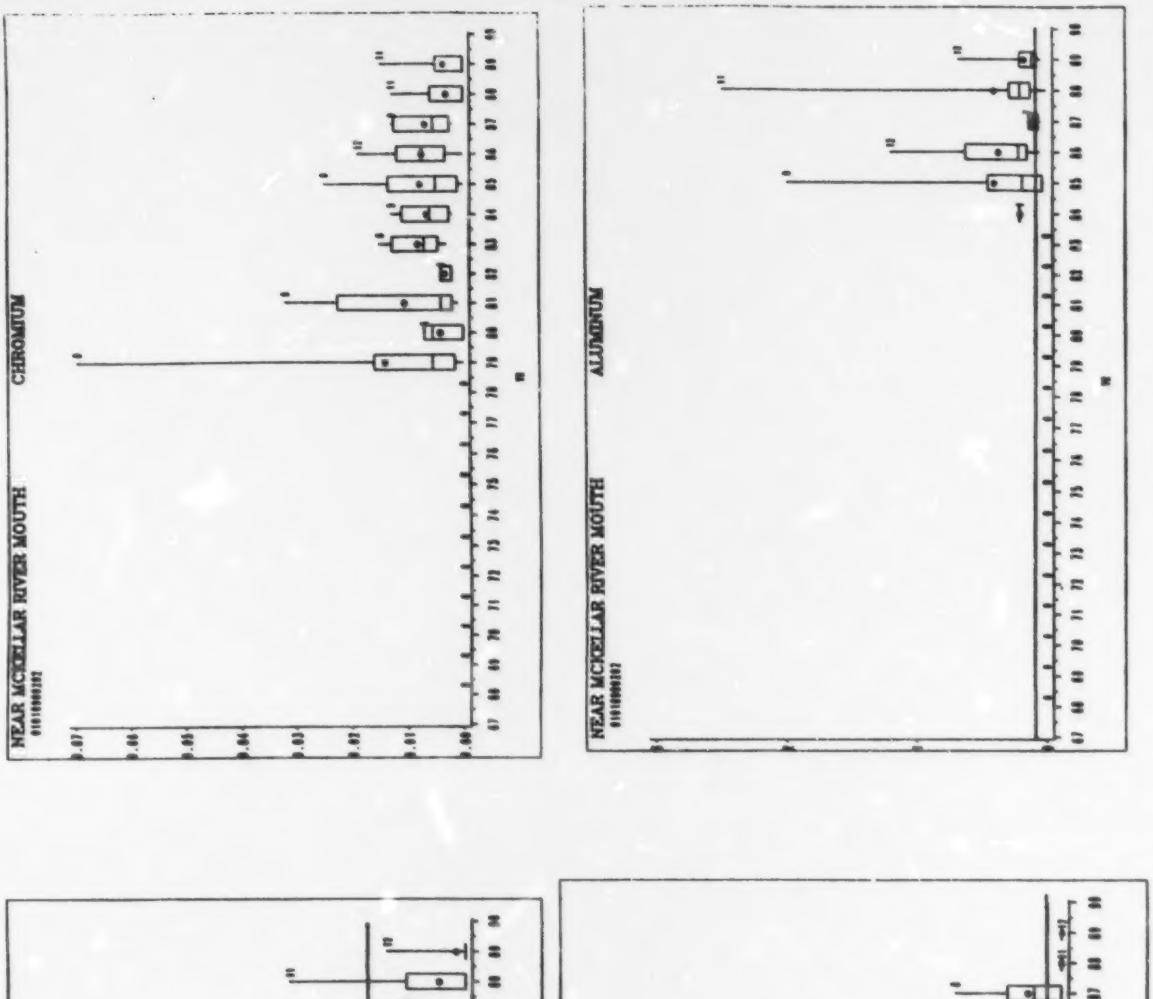


Fig. 101. Water quality in McKellar River at mouth.

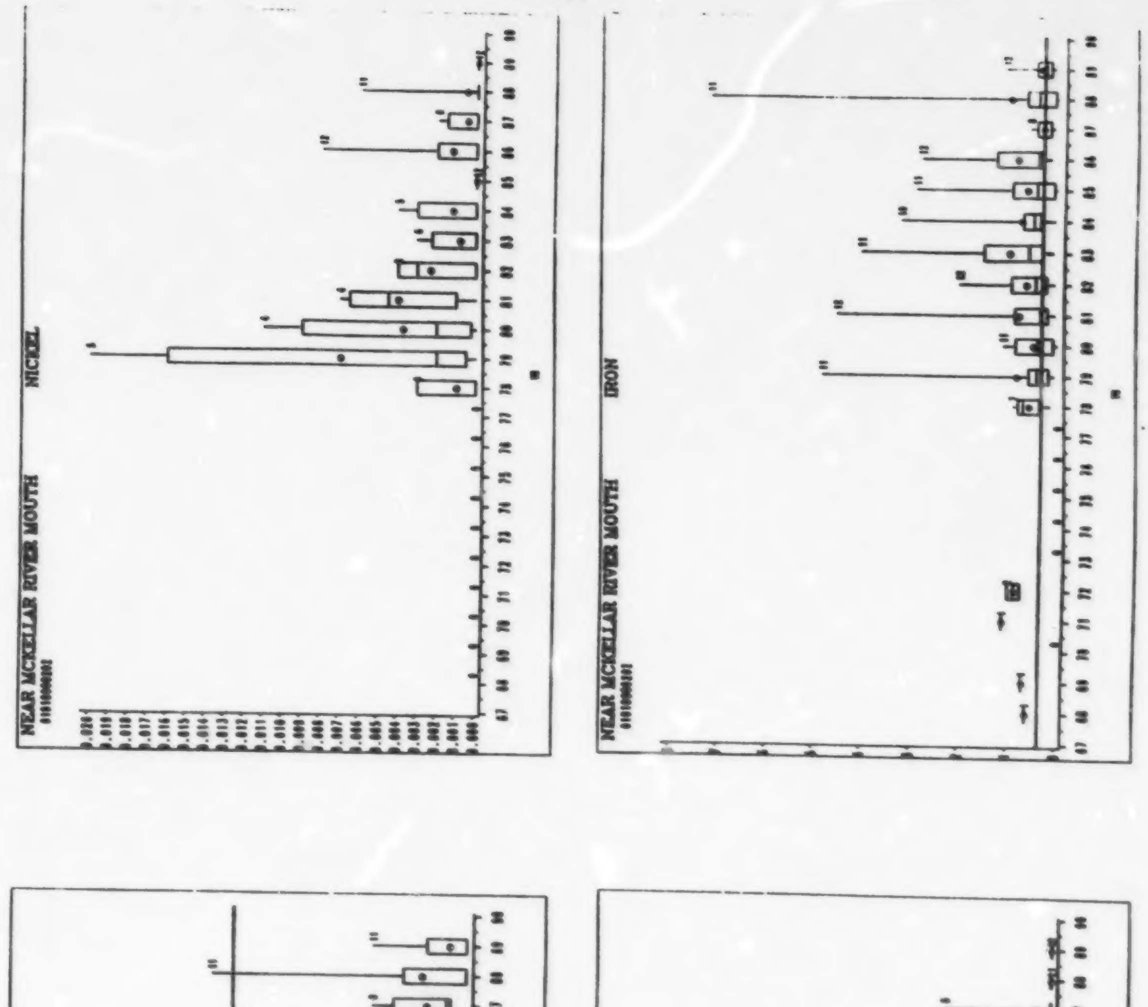


Fig. 102. Water quality in McKellar River at mouth.

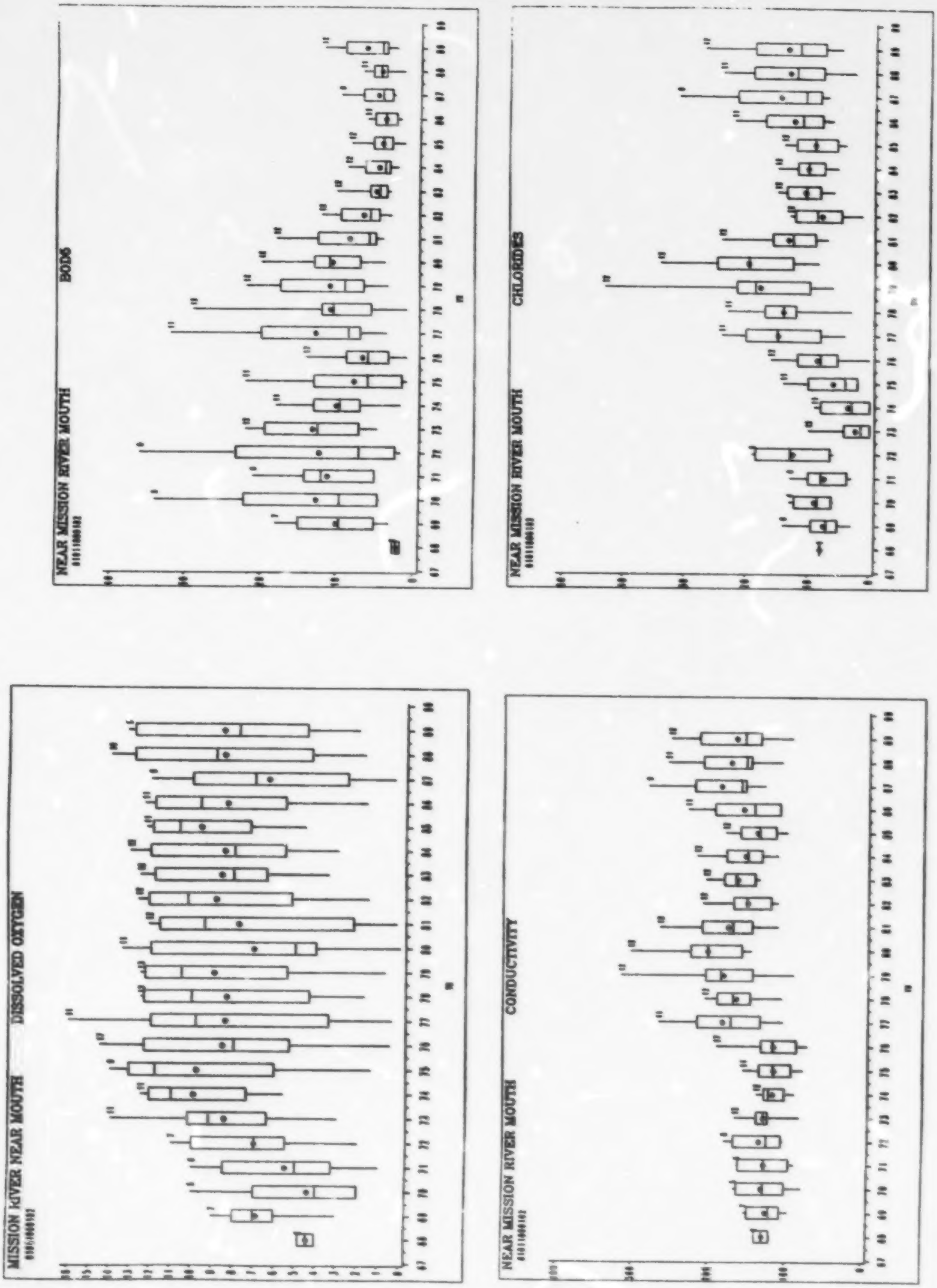


Fig. 103. Water quality in Mission River near mouth.

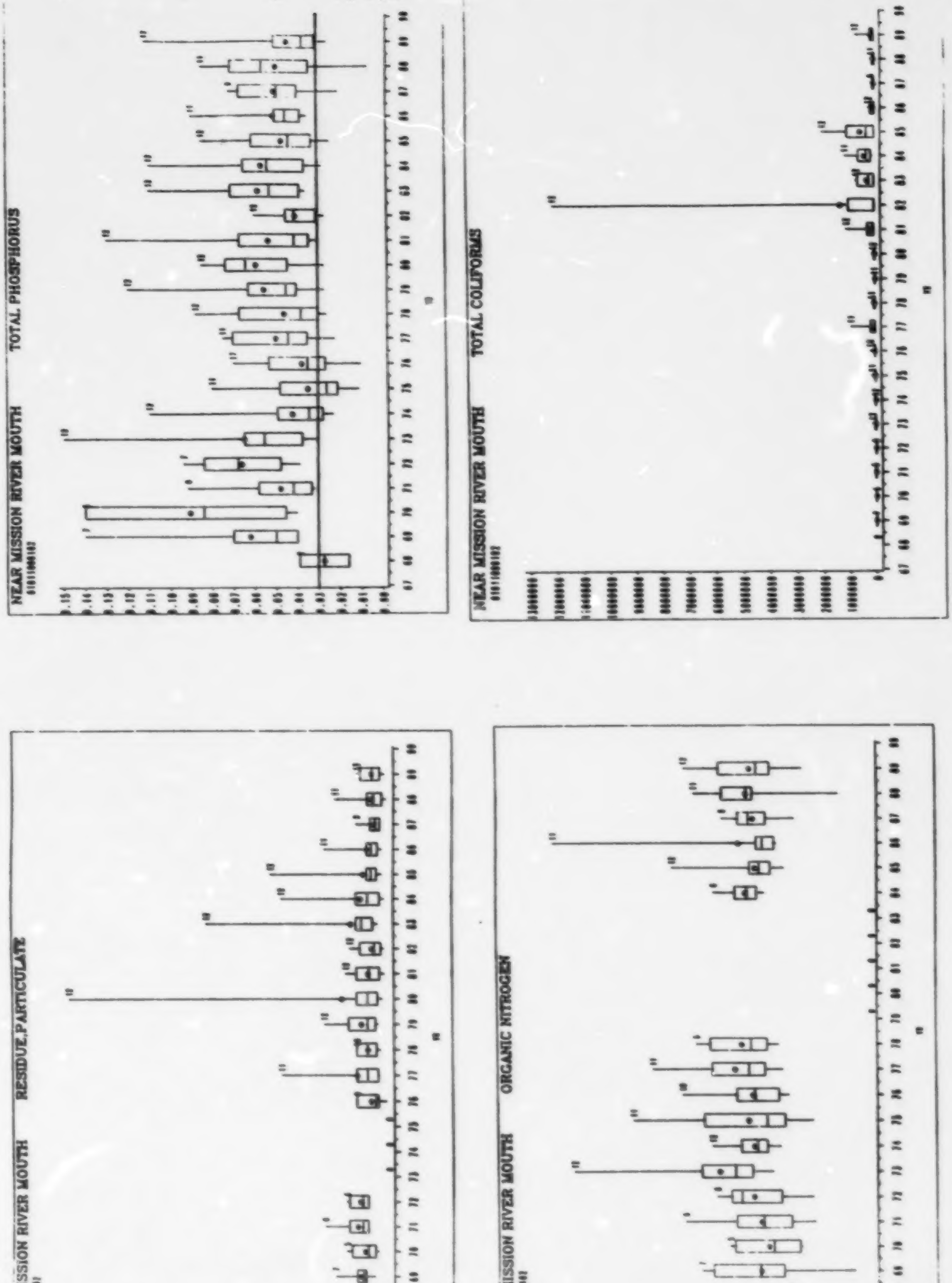


Fig. 104. Water quality in Mission River near mouth.

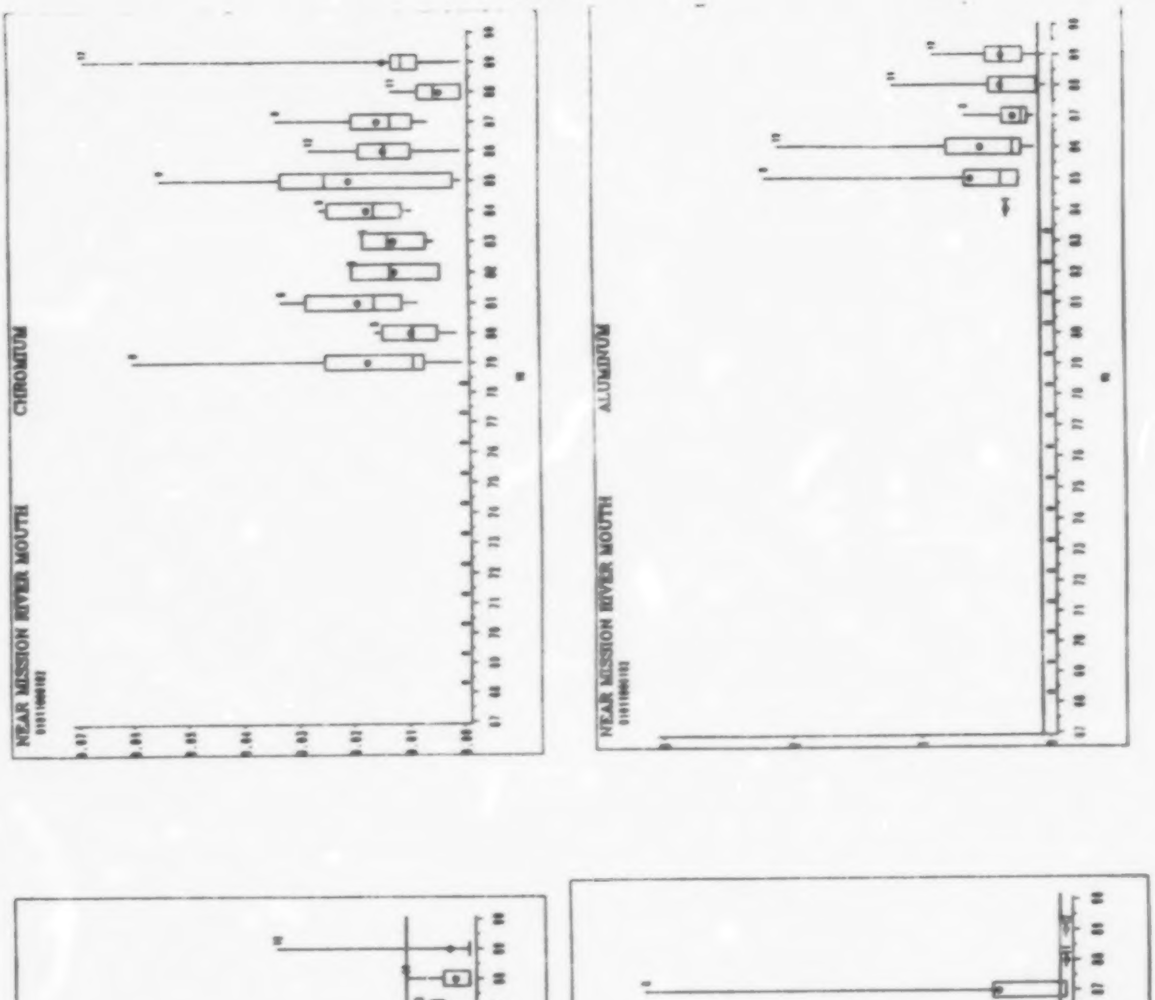


Fig. 105. Water quality in Mission River near mouth.

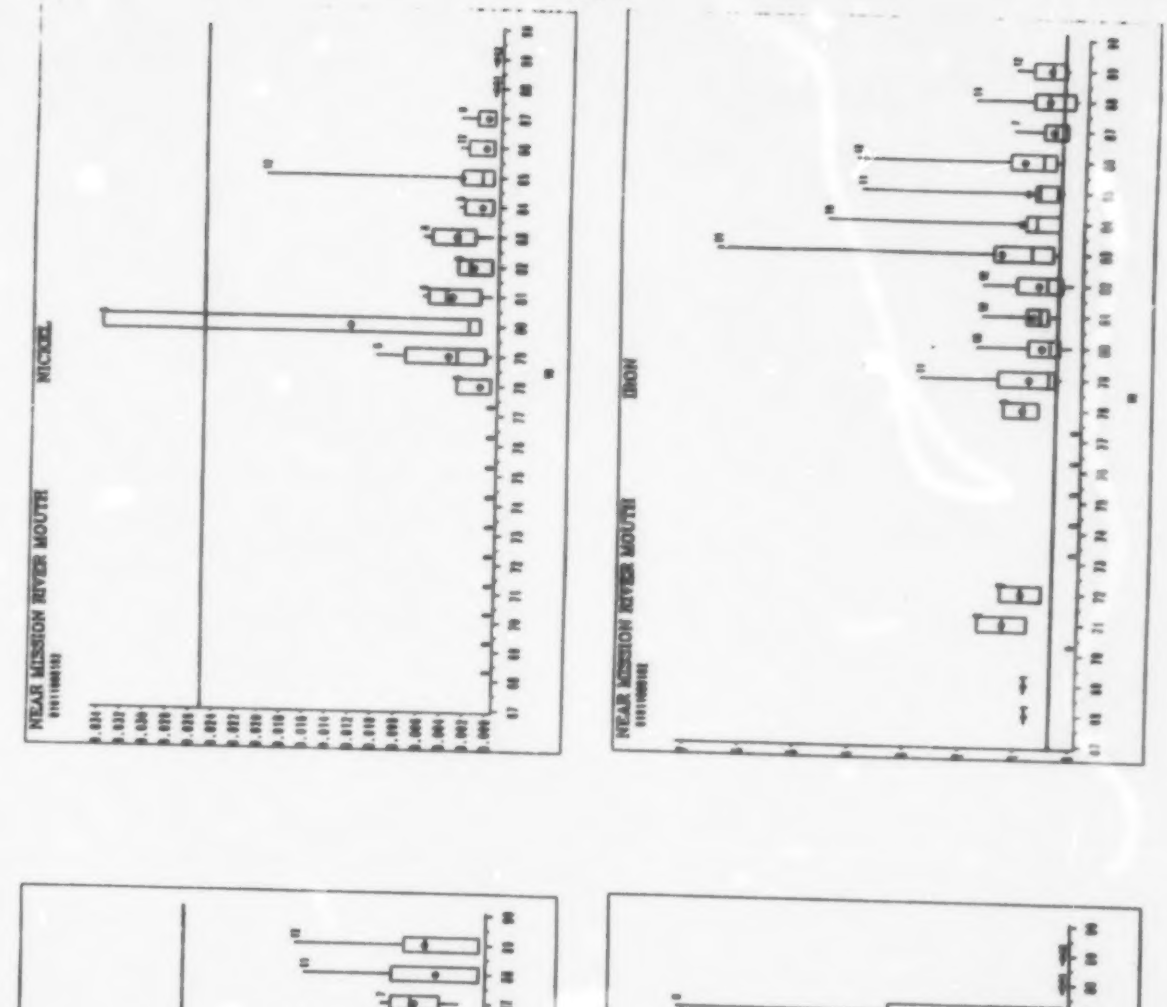


Fig. 106. Water quality in Mission River near mouth.

3.4 Summary, Wabigoon River

Water quality in the Wabigoon River is strongly influenced by the presence of a large kraft pulp and paper mill complex. Assimilation of industrial and municipal wastes also is affected by flows in the river. Improvements in key parameters such as BOD_5 reflect the installation of secondary treatment in 1983. Median values of several parameters (chlorides, conductivity, nutrients, and mercury) were higher at Minnitaki than immediately downstream from the mill. No immediate explanation for this is apparent. Bacteria levels were extremely high near the mill. Values decline downstream but at times exceeded standards for swimming as far downstream as Quibell.

Mercury data collected in routine sampling and analysis before 1983 may not be reliable. Revised procedures and methods were used in a special study of mercury contamination undertaken by the OMOE. Results from that study (Parks 1988) provided more reliable data and form the basis for questioning pre-1983 data. Levels measured after the early 1980's are dramatically lower, especially immediately downstream from the mill. Two exceedences of the PWQO were reported in 1989 at the new "mercury" station. Other metals showed few exceedences, and were very low in 1988 and 1989.

Station code: 19-0001-005-02
Location: upstream from Canadian Pacific Forest Product Ltd. (Figs. 108-111). Established 1968
Lat.: 49 46 20.06 **Long.:** 92 50 47.56
UTM: 15 511050 5513100
Station type: surveillance - background; special studies - regional assessments
Test groups: TBWQM3 TBCM5 +SS04UR +HGUT
Receivers: English River, Winnipeg River

Station code: 19-0001-006-02
Location: at golf course bridge, Dryden (Figs. 112-115). Established 1968
Lat.: 49 47 21.61 **Long.:** 92 51 12.37

UTM: 15 510550 5515000
Station type: point sources - industrial
Test groups: TBWQM3 TBCM5 +SS04UR +HGUT
Receivers: English River, Winnipeg River

Station code: 19-0001-038-02
Location: at Hwy. 17 (Fig. 124). Established 1987
Lat.: 49 48 56.00 **Long.:** 92 52 28.00
UTM: 15 509100 5517875
Station type: special studies - regional assessments
Test groups: +HGUT
Receivers: English River, Winnipeg River

Station code: 19-0001-035-02
Location: at Minnitaki sideroad (Figs. 116-119). Established 1980
Lat.: 49 51 02.00 **Long.:** 93 05 22.99
UTM: 15 493550 5521800
Station type: point sources - waste water treatment plant, industrial
Test groups: TBWQM3 TBCM5 +SS04UR +HGUT
Receivers: English River, Winnipeg River

Station code: 19-0001-036-02
Location: Hwy. 609 near Quibell (Fig. 120-124). Established 1980
Lat.: 49 57 29.81 **Long.:** 93 24 01.63
UTM: 15 471275 5533850
Station type: point sources - waste water treatment plant, industrial
Test groups: TBWQM3 TBCM5 +SS04UR +HGUT
Receivers: English River, Winnipeg River

Abatement History

Canadian Pacific Forest Products, Dryden (formerly Great Lakes Forest Products, Reed Limited, Dryden Paper Company)

There has been a kraft mill on the Wabigoon River at Dryden since 1913. Current production averages about 800 tonnes per day (t/d) for pulp and 600 t/d for paper. Since 1987, annual production has been approximately 30,000 tonnes/year of hardwood pulp.

A chlor-alkali plant at the Dryden mill was the source of mercury that contaminated over 250 kilometers of the Wabigoon-English River system in the 1960's. In 1970, abatement measures sharply curtailed mercury losses, and in 1975, the mercury cells were dismantled. Despite almost complete elimination of mercury discharges from the mill, biota in downstream reaches continue to exhibit high mercury levels (Parks et al. 1991).

In 1980, a primary clarifier was installed to reduce the extensive deposition of fibre downstream of the mill. In 1983, an aerated secondary treatment basin was constructed, to reduce BOD_5 and suspended sediment loading to the Wabigoon River. Effluent loadings have been reduced from about 48 t/d BOD_5 and 26 t/d of suspended solids to present annual averages of 2.4 and 5.0 t/d, respectively. Daily effluent flows also have been reduced during this period, from about 141,000 cubic meters per day to approximately 94,300 cubic meters per day. Since 1987 adsorbable organic halogen (AOX, a surrogate for measuring total organically-bound chlorine) loadings have decreased to 2.4 kilograms per tonne as a result of the partial substitution of chlorine with chlorine dioxide (ClO_2).

Plans are underway to upgrade the ClO_2 generator to increase the rate of ClO_2 substitution. Studies currently are underway to investigate the effects of ClO_2 substitution on effluent treatment. The company also plans to reduce short-circuiting in the aeration basins, and to upgrade the mixing units.

Municipal Waste Water Treatment Plant, Dryden

The Town of Dryden operates a contact stabilization plant (population served-6,900). Final effluent discharged below the Old Golf Road monitoring station meets OMOE objectives.

Water quality, Wabigoon River (Figs. 108-124 and Table 7)

Water quality in the Wabigoon River has been monitored at two sites since 1968; two sites were added further downstream from the pulp and paper mill in Dryden in 1980, and an additional mercury station was added in 1987. Previous to 1973, sampling was generally on a monthly basis; since 1983, samples were obtained approximately nine times per year. Mercury at all locations have been measured using a lower detection level (.005 ug/ℓ) than routine analysis (.01 ug/ℓ) since 1985. Fecal coliforms were discontinued in 1984.

Conventional Parameters

Conventional parameters except dissolved oxygen and pH were markedly lower at the upstream station than at any of the downstream locations. Upstream values have fluctuated somewhat over the entire period of record, and showed extreme values for several parameters in 1977. There has been a reduction in the variability associated with upstream nutrient data since 1983. Upstream phosphorus levels almost always exceeded the PWQG for phosphorus (0.03 mg/ℓ) prior to 1988.

Water quality at the golf course station (-0001-006-) differed significantly from the upstream station. Several trends were apparent in the data during three time periods: pre-1980, the early 1980's and 1983 through 1989. (As at the upstream station, the 1977 data indicated extreme values with high variability.) BOD_5 and suspended solids were lower after 1983, a reflection of the installation of secondary treatment basins at the mill. Since 1982, pH has been less variable.

Chlorides, conductivity, and total dissolved solids have all been more variable since 1980. These parameters in addition to sulphates and nutrients showed a similar pattern between 1982 and 1989. Low median values were reported in 1982 through 1985 followed by record high levels in 1987 (except for suspended solids). Values for these parameters declined in 1988 and 1989.

All downstream stations exibited similar patterns for several parameters. BOD_5 and coliform bacteria showed dramatic reductions after 1982 and 1983; conductivity, chlorides, sulphates, and nutrients declined then rose sharply in 1987. After 1987 all parameters noted above declined.

Water quality downstream of the golf course, at the Minnitaki and Quibell stations, is affected by effluent from both the pulp mill and the waste water treatment plant, which discharges to the river below the golf course. Chlorides, conductivity and mercury levels are higher at Minnitaki than at the golf course station. Long term median values for the above parameters were 37 mg/ℓ and 25.5 mg/ℓ; 284 uhmos/cm and 234 uhmos/cm; and .021 ug/ℓ and .009 ug/ℓ at Minnitaki and the golf course respectively. Nutrient levels were also higher at Minnitaki than at the golf course station; dissolved oxygen levels and pH are lower (see Table 7).

It is not possible on the basis of this review to distinguish between contaminants that originated at the mill and those introduced further downstream. Some tend to be most evident near the point of discharge and others, like oxygen depletion, may be more evident further downstream.

A preliminary review of total annual flow of the Wabigoon River at the dam operated by CPFP, Dryden, initially showed no correlation between the pattern for conventional dissolved parameters and flow. However, original company data (Fenton, M, 1991) suggest that the extremely high flow values published for 1987 are in error. A visual inspection indicated that a correlation probably does exist between certain water quality parameters and the original discharge data.

Total coliform levels were extremely high below the mill; prior to 1987 they typically were as high as 10 million counts/100 ml. Since then they have been reduced by a factor of 10. Downstream of Minnitaki they were approximately another factor of 10 lower than at the golf course station. Near Quibell they were down to less than 1000 counts/100 ml approximately half the time.

Metals

In 1969 through 1971, concentrations for zinc at both the upstream and downstream locations were high (extreme values ranging from 0.110 mg/ℓ to 0.320 mg/ℓ). Similar values were reported on the Rainy River for the station upstream of the mill (Section 3.5). This suggests either that metal data has become more reliable or that an unidentified source existed upstream. Upstream levels fluctuated over the decade 1978-1987, showing higher median values before 1983. (The lower minimum values on Fig 110 are an artifact of higher detection limits at the time; levels below the detection limit are shown on the figures as zero's.) At the golf course station zinc levels were approximately double those upstream; they exceeded the old PWQO (0.3 mg/ℓ) only occasionally, and would meet the new level (0.016 mg/ℓ) most of the time. In 1987, zinc concentrations increased significantly at the golf course station and showed exceedances. In 1988, levels declined; zinc was below detection limits in 1989.

Copper levels at the downstream station at the golf course typically were slightly higher than upstream. They followed a pattern similar to zinc, with exceedances in 1987, and a decline in 1988-89.

Iron also was slightly higher downstream than upstream, and was consistently above the PWQO, with some declines in 1988 and 1989.

Two samples taken in 1969 analyzed for nickel were improbably high (0.09 mg/ℓ at both stations). Since then, there have not been PWQO exceedances; in 1987-89 nickel was undetectable.

Levels of mercury reported at all stations before 1982 were higher than the values reported in the literature. Parks (1988) reported average values for 1978-1981 of 0.007 ug/ℓ upstream in Wabigoon Lake and 0.026 ug/ℓ downstream at the inflow to Clay Lake; the median value at the upstream station in 1980, based on PWQMN data, was 0.07 μg/ℓ. Values reported by Parks (1988) were based on analyses for a special study that were done at a laboratory in

Winnipeg. Elevated values also were reported before 1983 on other waters with no point sources of mercury, i.e. the Nipigon and Pic Rivers (Figs. 49 and 42 and Appendix 2.1). Thus there is a strong suspicion that mercury data before 1983 in this report are unreliable. Sampling procedures and analytical techniques introduced in the mid 1980's (Mierle 1990) now provide more reliable results.

Mercury levels at the the old golf course downstream station declined dramatically in 1981. In 1989 mercury was detected twice (at 0.007 µg/ℓ) in nine samples.

Mercury levels at a distance from the mill also have declined, but were higher than at the closest downstream station. At Hwy 17 there were two values above 0.02 µg/ℓ in 1989, and six samples below detection.

Median values for other metals are summarized in Appendix 3.2.

3.5 Summary, Rainy River

Water quality in the Rainy River has been extensively monitored and reported. In part this is because of its location on the Canada-USA border. Two kraft pulp and paper mills began operation at the outflow of Rainy Lake in 1968 and 1971. Other sources of contaminants include six sewage discharges, run-off from urban, cottage and agricultural development, as well as atmospheric and natural sources.

When the upstream station is compared to other relatively unpolluted rivers in the area, the Rainy River has the lowest values for alkalinity, conductivity, phosphorus and metals.

Values downstream show a complex pattern both spatially and through time. This seems to reflect the influence of numerous sources in addition to the mills, as well as fluctuating flows in the river. Downstream locations exceeded the PWQG for phosphorus most of the time, although levels are declining. Iron, probably from natural sources, usually exceeded the PWQO (0.300 mg/ℓ). Other metals were usually low, with occasional exceedences. Bacterial contamination exceeded standards for swimming all along the river. However, the actual source of bacteria (i.e. industrial, rural or residential) cannot be distinguished.

Station code: 19-0001-004-02
Location: Upstream from Fort Frances Toll Bridge
(Fig. 125-128) Established 1968
Lat.: 48 36 19.61 **Long.:** 93 23 12.96
UTM: 15 471475 5383450
Station type: protection of uses - fisheries protection, recreation surveillance - background
Test groups: TBWQM4
Receivers: Lake of the Woods, Winnipeg River

Station code: 19-0001-012-02
Location: Downstream from Fort Frances North
(Figs. 129-132) Established 1969

Lat.: 48 32 39.69 **Long.:** 93 28 59.29

UTM: 15 464340 5376700

Station type : point sources - waste water treatment plant industrial point source; protection of uses - fisheries protection

Test groups: TBWQM4

Receivers: Lake of the Woods, Winnipeg River

Station code: 19-0001-011-02

Location: Above Emo (Figs. 133-134) Established 1969

Lat.: 48 37 33.67 **Long.:** 93 50 02.01

UTM: 15 438550 5386000

Station type: protection of uses - fisheries protection

Test groups: TBWQM4

Receivers: Lake of the Woods, Winnipeg River

Station code: 19-0001-003-02

Location: Downstream of Emo (Figs. 135-136) Established 1968

Lat.: 48 37 31.47 **Long.:** 93 54 51.43

UTM: 15 432625 5386000

Station type: point sources - waste water treatment plant; protection of uses - fisheries protection

Test groups: TBWQM4

Receivers: Lake of the Woods, Winnipeg River

Station code: 19-0001-009-02

Location: Downstream from confluence with Baudette River (Figs. 139-140) Established 1969

Lat.: 48 43 10.93 **Long.:** 94 35 28.91

UTM: 15 0382950 5397300

Station type: point sources, protection of uses - fisheries protection

Test groups: TBWQM4

Receivers: Lake of the Woods, Winnipeg River

Station code: 19-0001-010-02

Location: Upstream from confluence with Baudette River (Figs. 137-138) Established 1969

Lat.: 48 42 58.13 **Long.:** 94 13 18.81
UTM: 15 385600 5396850
Station type: protection of uses - fisheries protection
Test groups: TBWQM4
Receivers: Lake of the Woods, Winnipeg River

Abatement History

Boise Cascade Canada Ltd. (Fort Frances), Boise Cascade Corp. (International Falls)

The Boise Cascade Corporation has produced pulp, paper, and power at the outlet of Rainy Lake since 1909. Kraft mills on both sides of the river (Fort Frances, Ontario and International Falls, Minnesota) have been in operation since 1968 and 1971, respectively. Groundwood specialty papers also are produced at the Fort Frances Mill. The combined production from both mills averaged more than 1300 tonnes of paper per day between 1983 and 1989. Effluent discharges averaged 206,800 m^2/day during a survey in the summer of 1986 (Beak, 1990).

A detailed summary of abatement measures for both mills is given in The Rainy River Water Quality Study (Beak 1990). The following information was obtained from that report and OMOE Kenora District files. The Fort Frances kraft mill implemented secondary treatment since start-up in 1971. Primary treatment was installed at International Falls in 1970, with additional upgrading in 1975 and 1979. The most significant improvements occurred between 1978 and 1982 at the International Falls mill (Beak 1990) and between 1980 and 1982 in Fort Frances (Beak 1990). Effluent loadings at the Canadian mill have decreased since the early 1970's from 20 tonnes per day each of BOD_5 and suspended solids, to 10 and nine metric tonnes per day, respectively. In 1985 and 1986, a spills collection system was installed at the Fort Frances mill. Further reductions in toxicity and organo-chlorides (neither of which are reflected in data summarized in this report) are expected as a result of improvements scheduled for 1991.

Waste Water Treatment Plants

The Ministry of the Environment operates a primary treatment plant with anaerobic digestion for the Town of Fort Frances (population served, 8800). Infiltration and extraneous flow problems have occurred and currently are being corrected. Plant efficiency criteria are not always met. Upgrading to full secondary treatment is in the preliminary design phase.

The OMOE also operates a one-celled lagoon for the Township of Emo (population served, 750), and a two-celled lagoon for the Town of Rainy River (population served, 985). The lagoon at Emo is currently overloaded and the effluent requirements are exceeded on occasion. Both systems discharge seasonally to the Rainy River.

In Minnesota, there are two municipal wastewater discharges to the Rainy River. The North Koochiching Sanitary Sewer District (International Falls) wastewater treatment facility is a continuous discharge, while the lagoons at Baudette are discharged seasonally.

The Government of Canada operates a rotating biological contactor (RBC) plant for the Rainy River First Nations (I.R. 49) at Manitou Rapids (population served, 330). This plant has a continuous effluent discharge to the Rainy River.

Water Quality, Rainy River (Figs. 125 - 140 and Table 8)

Sample collection was initiated in 1968 and 1969. Previous to 1981, sampling programs were on a monthly schedule; since 1981 this frequency was reduced to six to eight times yearly. Metals were sampled quarterly. Fecal coliform determinations were discontinued in 1984. As of 1990 Station -0001-004- was superseded by -0001-039-, and two stations, -0001-003- and -0001-010-, were discontinued.

These data have been reported extensively. Annual Status Reports are prepared for the International Rainy River Water Pollution Board. In 1990 Boise Cascade Corporation published the results of a major inter-agency study of water quality on the River (Beak 1990). That report included summaries of flows and water quality data, other studies that have been carried out, and an historical review of abatement initiatives. In 1988, subsequent to the preparation of Beak's report (1990), fish kills were reported in the Rainy River during a period of low flows and hot weather.

The following overview is based on median (not mean) values (Table 8), and also differs from the Beak report in incorporating only OMOE stations.

Conventional Parameters

Comparisons between surface water quality from the upstream station and that of other major rivers in the region (Table 4) show that the Rainy River had the lowest levels of alkalinity and conductivity (long term median of 20 mg/ℓ and 54 uhmos/cm respectively), low levels of metals, similar to those found on the Nipigon River, and low levels of phosphorus.

BOD_5 values were highest at the station immediately downstream of the mills (-0001-012-). Low oxygen concentrations (2 mg/ℓ) that did not meet the PWQO were reported at this station, although median values were less variable than further downstream. Median values for other parameters - conductivity, suspended solids, and nutrients - increase above Emo and continued to rise further downstream. The lowest long-term median values for dissolved oxygen (9.0 mg/ℓ) extended from the station above Emo, below major tributaries (the Big and Little Fork Rivers) and other non-point source, to upstream of Baudette. The highest median values for phosphorus and suspended solids were reported downstream of Emo (.034 mg/ℓ and 7 mg/ℓ respectively). Conductivity reached its highest long term median value at the station upstream of Baudette (90 uhmos/cm).

There are few obvious time trends in the data. Only phosphorus levels seem to have declined, since the late 1970's or early chlorides and conductivity), show a pattern of year to year fluctuations associated with flow rates. There is evidence of a gradual overall increase from the relatively low early concentrations. BOD_5 and suspended solids fluctuate, apparently independently of each other; they have not improved nor deteriorated over time (Beak 1990).

Total and fecal coliform levels were high at the first station downstream from the mill, and, although they were lower at the stations further down river, median values at all stations exceeded desirable levels. Water is considered impaired and unfit for swimming if the geometric mean for total coliform for a series of samples is greater than 1000 counts per 100 ml, or if fecal coliform (geometric mean for a series) exceeds 100 counts/100 ml. Median coliform counts decreased steadily from the Fort Frances station to upstream of Baudette, but increased slightly at the station downstream of Baudette.

Throughout the 1970's extremely high values (millions of counts/ 100 ml) were reported occasionally at all stations. These levels have not been reported in the 1980's. This probably reflects a real change in water quality as well as an improvement in data reliability.

Another limitation on data analysis is the difficulty in accurately distinguishing bacterial contamination from mills and that of agricultural runoff or waste water treatment plants. Laboratories found that the bacteria, *Klebsiella*, which is common in mill process water, may be counted as fecal coliforms. Data on the bacteria *E.coli and Pseudomonas*, indicate a source of human or animal waste contamination. These data are not consistently available at the downstream stations.

Metals

Parameters reported and summarized include: cadmium, copper, iron, nickel and zinc. Exceedances of PWQO's were reported in 1981, 1982 (and earlier) upstream for cadmium, copper, iron, nickel and zinc and at some downstream stations for cadmium, copper and iron. Copper was especially high at the upstream station. During the period of 1972 to 1974, levels ranging between 0.1 mg/ℓ and 1.4 mg/ℓ were reported on 14 occasions. Nickel exceedances upstream included 12 values between 0.04 and 0.53 mg/ℓ between 1968 and 1974, zinc ranged from 0.04 to 0.32 mg/ℓ 17 times between 1968 and 1974. Since the early 1980's there were fewer exceedances downstream and maximum values have been less extreme. These differences suggest either that metal data have become more reliable since 1983, or that some unknown source of contamination existed upstream. These extreme values are not included in the figures for copper, zinc and nickel so as to provide an appropriate scale for more reliable current data. In 1989 exceedances of cadmium and copper were reported at the upstream station; cadmium also was in exceedance at the downstream station in Fort Frances.

In 1985, most downstream stations reported one exceedance each of cadmium; at the station downstream of Baudette the concentration was as high as 0.01 mg/ℓ. Copper exceeded the PWQO once in 1985 downstream of Emo (0.028 mg/ℓ); zinc exceeded the PWQO at the two stations near Emo (maximum value of 0.033 mg/ℓ). Only iron consistently exceeded the PWQO (0.300 mg/ℓ); this occurred more commonly near Emo and Baudette, and is consistent with Beak's (1990) information that tributaries contribute to iron loadings. Mercury was detectable occasionally but never exceeded the PWQO.

3.6 Summary, Winnipeg River

The two stations on the Winnipeg River were established in 1968. Although located to monitor the effect of pulp mill effluent on the river, they also indicate the general quality of water as it leaves the Lake of the Woods system and flows towards Manitoba.

Most conventional parameters increased by a factor of between 1.5 and 3 between the upstream and downstream location. This relatively modest effect on water quality may reflect the relatively high flow rates in the river (see Appendix 1.3) relative to the volume of effluent discharged. Most parameters such as phosphorus and metals are within provinical standards.

Since 1977, sampling for conventional parameters was done monthly; metals were first sampled in 1978. Collection frequency has been reduced since 1987. Analysis for fecal coliforms was discontinued in 1984.

Station code: 19-0001-001-02
Location: At first CPR bridge west of Main Street, Kenora (Figs. 141-143) Established 1968
Lat.: 49 46 13.83 **Long.:** 94 29 58.10
UTM: 15 392025 5513975
Station type: surveillance - background
Test groups: TBWQM3 + SIO3UR
Receivers: Winnipeg River

Station code: 19-0001-002-02
Location: Northwest of Old Fort Island (Figs. 144-146) Established 1968
Lat.: 49 47 06.67 **Long.:** 94 30 43.49
UTM: 15 391150 5515625
Station type: point sources - industrial point source
Test groups: TBWQM3 + SIO3UR
Receivers: Winnipeg River

Abatement History

Boise Cascade Canada

Pulp and paper operations at this site date back to the early 1920's. Boise Cascade currently operates an integrated ultra-high yield sulphite, groundwood and newsprint facility which produces about 750 t/d of newsprint. A dry debarking plant and boiler house complement the main production plant. Construction of a new thermo-mechanical pulp mill has been deferred pending better economic conditions.

Since the early 1970's, effluent loadings of BOD_5 and suspended solids to the Winnipeg River have been reduced from about 40 t/d and 15 t/d to present levels of about 25 t/d and 3.5 t/d, respectively. Daily effluent volumes have also been halved to approximately 48,000 cubic metres per day.

Effluent streams undergo primary treatment in a large clarifier system which was installed in 1971. Domestic sewage is diverted to the municipal sewage collection system. The company meets compliance levels set by its Certificate of Approval for BOD_5 (35 t/d) and suspended solids (4.5 t/d). Fish kills have occurred downstream, most recently in 1987 and 1988 at times of unusually low flows in the river.

Pilot plant studies into the use of an activated sludge system to further reduce BOD_5 and improve toxicity are underway in anticipation of changing compliance levels under the MISA program.

Wastewater Treatment Plant

A contact stabilization plant operated by the Town of Kenora serves Kenora, Keewatin and Jaffray Melick (population served: 12,000). It operates satisfactorily and meets OMOE objectives. Upgrading is planned once funding has been arranged.

Water Quality, Winnipeg River (Figs. 141-146)

Conventional Parameters

Median values for all parameters are given in Appendix Table 3.2. Most parameters were somewhat lower upstream than downstream: BOD_5 (0.7 vs 2.5 mg/ℓ), suspended solids (2.0 vs 4.0 mg/ℓ), turbidity (1.6 vs 2.8 mg/ℓ), zinc (0.001 vs 0.002 mg/ℓ) and total coliform (170 counts/100 ml vs 4350 counts/100 ml). Median values for pH were noticeably lower downstream (7.7 vs 7.4).

BOD_5 near the Old Fort Island station has remained relatively constant (median value approximately 2.5 mg/ℓ) since 1977; the highest median since then was reported in 1988 (3.9 mg/ℓ). Dissolved oxygen has remained above 6 mg/ℓ since 1973. Suspended solids showed a high maximum value (but not median) of 35 mg/ℓ in 1988.

Values for total and fecal coliforms fluctuated greatly (1-4,100,00 and 1-3600 counts/100 ml, respectively). Between 1978 and 1986 levels above 1000 counts per 100 ml were reported occasionally upstream, and in virtually every sample downstream. Impairment has decreased such that less than half the samples taken since 1986 have had undesirably high bacteria levels.

Metals

Metals for the two Kenora stations remained low throughout the sampling period; only zinc exceeded PWQO's. All exceedances occurred previous to 1980 (maximum value 0.6 mg/ℓ); long term median concentrations for zinc at both the upstream and downstream locations were 0.001 mg/ℓ and 0.003 mg/ℓ, respectively.

3.7 Summary, Red Lake Area

Three water quality stations were established in 1971 and 1972 to monitor the impact of two gold mines in Balmertown on water quality at the outflow from Balmer Lake, in Balmer Creek, and the Chukuni River. Balmer Creek also is affected by discharges from a waste water treatment plant, as well as urban and non-point source industrial run-off.

Water quality at the outflow was severely contaminated for most of the parameters measured. Although the abatement measures taken early in the 1970's and again in 1984-85 resulted in some improvement in water quality, levels of contaminants continued to be high. In 1988 and 1989 several parameters were as high as at any time since 1974. Slight increases in conventional parameters also were observed in nearby Red Lake in 1988 and 1989. Conductivity, sulphates, nutrients, cyanide, and some metals (zinc, copper, nickel, arsenic, and mercury) are of particular concern. These metals exceeded Mining Effluent Guidelines (OMOE 1979).

These parameters showed some improvement further downstream, but still exceeded Mining Effluent Guidelines; metal levels were approximately half those found at the outflow of Balmer Lake. Other parameters, BOD_5, nutrients and bacteria, increased, showing the influence of the waste water treatment plant.

Water from Red Lake flows into the English River through the Chukuni River. A monitoring station was established on the Chukuni River in 1968, just downstream from the confluence of Balmer Creek. Levels of copper and nickel occasionally exceeded PWQO's, suggesting that contaminants from Balmer Creek influenced water quality in the river.

Red Lake proper receives surface drainage from three communities and discharges from two waste water treatment systems. Between the late 1930's and 1971 there were several gold mines that dumped tailings into the lake or along the shoreline. Water quality has been monitored at two stations near the areas of greatest potential contamination since 1968. Conventional parameters tend to be low but variable, with fluctuations that may reflect natural cycles. Metals occasionally exceeded PWQO's, especially for copper and cadmium in the late 1970's and early 1980's. Most metals were low or undetectable in 1988-89.

The impact of a base metal mine that operated on Bruce Lake from 1966-1986 is monitored downstream on the Troutlake River. The station was established in 1968. Levels of several metals were high in the early 1980's, with occasional exceedences of cadmium, iron, and copper.

3.7.1 Balmer Creek/Chukuni River

Station code: 19-0001-016-02
Location: At Balmer Lake outlet (Figs. 148-152)
Established 1971
Lat.: 51 03 38.23 **Long.:** 93 43 43.71
UTM: 15 448925 5656600
Station type: diffuse sources - extractive industrial land
Test groups: TBWQM5 TBCM6
Receivers: Chukuni River, English River, Winnipeg River

Station code: 19-0001-032-02
Location: 500 feet upstream of Chukuni River
(Figs. 153-156) Established 1972
Lat.: 51 01 48.00 **Long.:** 93 44 8.94
UTM: 15 448400 5653200
Station type: diffuse sources - waste water treatment plant; diffuse sources -extractive industrial land.
Test groups: TBWQM5 TBCM6
Receivers: Chukuni River, English River, Winnipeg River

Station code: 19-0001-015-02
Location: Chukuni River, downstream from Balmer Creek (Fig. 107) established 1971
Lat.: 51 01 28.80 **Long.:** 93 43 32.70
UTM: 15 449100 5652600

Station type: diffuse sources - extractive industrial land
Test groups: TBWQM5 TBCM6
Receivers: Chukuni River, English River, Winnipeg River

Abatement History

Dickenson Mines Ltd., Balmertown, Ont.

The Company operates a 900 tonne per day underground mine and surface mill using the processes of crushing, grinding, flotation, cyanidation and refining to produce gold bullion. Mining operations at this site date back to the late 1940's.

Raw effluent from the operation is directed to a tailings disposal system followed by secondary and tertiary polishing ponds for cyanide removal. The tailings dam initially was constructed in 1978-1979 and collapsed in May 1979. Between 1979 and 1984, restoration and expansion took place. This new dam failed in April 1985; a major reconstruction was carried out in 1985.

In 1984, a spill-way was constructed to divert mill water to a polishing pond; prior to the diversion it was discharged directly into Balmer Lake. From the polishing pond, the water is discharged into Balmer Lake by percolation through the rockfill dam (Gadsby and Chantler, 1988).

The final effluent discharges into Balmer Creek and ultimately the Chukuni River. The effluent discharge point is shared with Campbell Mine. The final effluent is usually not acutely lethal to test fish and usually meets the cyanide contaminant limit of 2 mg/ℓ. Major process changes are planned to reduce arsenic and metal concentrations in the decant and, consequently, in the final effluent.

Placer Dome Inc.- Campbell Mine

The company operates a 1200 tonnes per day underground mine and surface mill using the processes of crushing, grinding, flotation, roasting, cyanidation and refining to produce gold bullion. A pressure oxidation system presently is being constructed to further reduce arsenic and metal concentrations in effluent and replace the former roasting circuit. Operations at this site date back to the 1940's.

Effluents are directed into a certified tailings disposal area. This discharge was relocated in April 1987. The tailings disposal site is a series of four holding ponds with approximately 300 days total retention time. Phase 1 of this tailings system was built in 1983. Throughout 1984-1988, there were several dam failures followed by reconstruction and expansion.

Final effluent is batch discharged depending on contaminant levels of cyanide, arsenic and heavy metals from Balmer Lake which is used as a tertiary clearwater pond. The receiving stream is Balmer Creek, which flows into the Chukuni River. The effluent discharge point is shared with Dickenson Mines Ltd. The final effluent is usually not acutely lethal to test fish and meets the contaminant limit for cyanide of 2 mg/ℓ.

Because of concern about the increasing levels of heavy metals in Balmer Lake, a study was conducted in 1988-1989 (EAG 1989) and another is ongoing to assess the reasons for recent increases in metal levels in the lake. The first study concluded that a very large proportion of the observed changes in heavy metal loadings in Balmer Lake can be accounted for by a reduction in dilution from mine wastes as a result of less run-off into Balmer Lake (EAG 1989).

Wastewater Treatment Plant

The OMOE operates an extended aeration plant for the Township of Golden (population 1,300) that discharges to Balmer Creek downstream from the Balmer Lake outflow. The plant experiences hydraulic overloading, but the effluent meets OMOE requirements. Flows are being monitored and problems are being discussed with the municipality.

Water Quality, Balmer Creek and Chukuni River
(Figs. 148 - 161 and Tables 9 and 10)

Balmer Creek and the Chukuni River stations have been sampled at least seven times yearly since 1979. Total coliform analyses were discontinued in 1984.

Conventional Parameters

Long term median values for several conventional parameters were high at the outlet of Balmer Lake. Values for chlorides, conductivity and suspended solids were 40.5 mg/ℓ, 505 umhos/cm and 10 mg/ℓ, respectively. Nutrient levels also were elevated; phosphorus 0.120 mg/ℓ, ammonia 1.30 mg/ℓ and organic nitrogen 2.70 mg/ℓ(long term medians from Table 9).

Extremely high values (see figures) were recorded in 1973 for BOD_5, suspended and dissolved solids, sulphates, and total phosphorus. By 1976 any elevated parameters had dropped significantly. Levels increased slightly again in 1977 and/or 1978. In the early 1980's, slight increases again were recorded in alkalinity, BOD_5, conductivity, chlorides, nitrogen and sulphates. Reductions were observed in 1985 and 1986. Since 1987, significant increases occurred in several parameters, resulting in levels of alkalinity, BOD_5, conductivity, sulphates, and nitrogen as high as any recorded since 1974. Maximum values for 1989 are listed in Table 9.

Total and fecal coliforms at the outlet of Balmer Lake generally were low. Fecal concentrations were usually below four counts/100 ml with a maximum count of 296 after 1975. Total coliforms ranged between 1-6000 counts/100 ml.

Metals

Over the period of record, levels of zinc, copper, nickel and arsenic have almost always exceeded PWQO's at the outlet of Balmer Lake; some frequently exceeded the Mining Effluent Guidelines. In general, levels of these metals and mercury showed peaks in 1974, the late 1970's and/or early 1980's and during 1988 and 1989. Improvements were seen in water quality in 1985 and 1986, after the construction of a dam which increased the retention time, and assimilation of contaminants in the lake. However, concentrations of these parameters have returned to the levels reported in the early 1980's. Copper and nickel exceeded Mining Effluent Guidelines (cumulative concentration of copper, zinc and nickel in a mine-mill effluent should not exceed 1 mg/ℓ) on at least one occasion in 1989; arsenic only occasionally met the effluent guideline (1 mg/ℓ). During the first half of 1989, mercury levels exceeded 0.2 µg/ℓ on all four sample dates.

Cyanide levels show a similar pattern, however the form of cyanide for which data are presented (total cyanide) has no PWQO. Data on free cyanide (PWQO = 0.005 mg/ℓ) are available only for 1988 and 1989; exceedances occurred in seven out of 16 samples and reached a maximum of 0.076 mg/ℓ.

Other metals that were elevated at the outlet included aluminum, cadmium, cobalt, iron and manganese.

Downstream Stations

Conventional Parameters

Nutrients and BOD_5 increased downstream (Table 9), at Balmer Creek upstream of Chukuni River, reflecting additional loading from the waste water treatment plant. Fecal coliforms also were detected at this station. In recent years only one metal, manganese, was as high or higher downstream than at the outflow. The median values of the metals of greatest concern were lower than at the outflow by the following factors: zinc, x 0.4; copper, x 0.5; mercury, x 0.6; nickel x 0.6; and arsenic, x 0.8. Exceedances of PWQO's occurred regularly in 1988 and 1989 for zinc, copper, nickel and arsenic at a time when no water/effluent was released from Balmer Lake.

No long term record of flow rates is available, however, the occurrence of extended periods of little or no flow is a major characteristic of this system. During periods of little or no discharge from Balmer lake, lower Balmer Creek effectively becomes an arm of the Chukuni River rather than a tributary.

Downstream of Balmer Creek in the Chukuni River, all the conventional parameters and nutrients were significantly lower than Balmer Lake. However, levels of copper and nickel occasionally exceeded PWQO's at this station. In 1989 a value of 0.05 ug/ℓ was reported for mercury, which was not usually detectable in the Chukuni River.

Microbial quality was generally good at both stations although fecal coliform occasionally exceeded 100 counts/100 ml prior to 1984.

3.7.2 Troutlake River

Station code: 19-0001-008-02
Location: At Hwy. 105 (Figs. 162-165) Established 1968
Lat.: 50 49 24.44 **Long.:** 93 25 29.18
UTM: 15 4780080 5630060
Station type: diffuse sources - extractive industrial land; surveillance - major tributary mouth
Test groups: TBWQM5 TBCM6
Receivers: Chukuni River, English River, Winnipeg R.

Abatement History

Steel Company of Canada - Griffith Mine

The Griffith Mine operated on the west shore of Bruce Lake near the outflow to Troutlake River between 1966 and 1986. During its lifetime, the mine removed a total of 183 x 10^6 tons of rock from two open pits that extended to the lake bottom (Anonymous 1986). Iron pellets were produced from the ore. Dykes and dredging were used to expose the bedrock and the lake bottom. This dredging was carried out during three periods: 1967-1968, 1973-1974 and 1979. In 1986, the mine closed. In decommissioning the mine, the

tailings basins were covered with water behind permanent water control structures.

Water quality, Troutlake River
(Figs. 162 - 165 and Tables 9 and 10)

Median values for several parameters are listed in Table 9. They were generally slightly higher than those reported for the Chukuni River, except for sulphates and bacteria. Phosphorus occasionally exceeded the PWQO of 0.03 mg/ℓ, fluctuating throughout the period of record with no obvious trend (median 0.027 mg/ℓ). In general, annual variation for all parameters was highest during the 1970's, narrowed through the 1980's and increased in 1987-1989. BOD_5, chlorides and nitrogen increased from record low values in 1986 to relatively high values in 1989. Over the period of record the pH has remained relatively constant (median 7.8).

Extremely high values were reported for zinc and copper in 1970 and 1971, however, values have rarely exceeded PWQO's since that time. Levels of several metals (arsenic, lead, nickel) also declined since the early 1980's. Cadmium has exceeded the PWQO of 0.0002 mg/ℓ twice in 42 samples since 1983. Iron was high with a median value of 0.35 mg/ℓ, but has declined consistently since 1978. Lead exceeded its PWQO of 0.005 mg/ℓ in 1980 and 1981, but has been low since then. High concentrations were reported for mercury in the late 1970's and early 1980's, but levels have been below detection since 1981. Zinc exceeded the PWQO only once, in 1987 (0.031 mg/ℓ). All of these improvements pre-date mine closure. Other metals meet PWQO's.

3.7.3 Red Lake

Station code: 19-0001-018-01
Location: In Bruce Channel, at McKenzie Island ferry crossing (Figs. 166-169) Established 1971
Lat.: 51 04 03.41 **Long.:** 93 49 34.76
UTM: 15 442100 5657450

Station type: diffuse sources - extractive industrial land; special studies - regional assessments
Test groups: TBWQM5 TBCM6
Receivers: Chukuni River, English River, Winnipeg River

Station code: 19-0001-033-01
Location: Howey Bay, 500 feet from shore (town of Red Lake (Figs. 170-173) **Established** 1972
Lat.: 51 01 20.96 **Long.:** 93 49 02.36
UTM: 15 442675 5652425
Station type: diffuse sources - extractive industrial land; special studies - regional assessments
Test groups: TBWQM5 TBCM6
Receivers: Chukuni River, English River, Winnipeg River

Abatement History

The shores of Red Lake have been the site of gold mining activity since the 1930's. Tailings from abandoned mines form the shoreline along the south and east shores of Howey Bay and parts of the Bruce Channel. The Cochenour-Willans Mine in Cochenour opened in 1939 and discharged tailings into the Bruce Channel adjacent to the sampling station until its closure in 1971. Across the channel on MacKenzie Island a large conical pile of waste rock marks the site of the MacKenzie Red Lake Gold Mine, which operated from 1935 to 1966.

More recently, the main potential influences on water quality in Red Lake have been from the townsites established on its shores: Red Lake, the Township of Golden (Cochenour), and the community on MacKenzie Island.

Wastewater Treatment Plants

The Ministry of the Environment operates an extended aeration plant for the town of Red Lake (population served: 1945). Effluent quality meets OMOE standards.

A septic tank system in Cochenour (population served:800) was replaced with a two-celled lagoon system in 1985. The effluent meets the OMOE objectives.

Water Quality - Red Lake (Figs. 166-173 and Table 9)

Sampling in Red Lake dates from 1971; since 1977 it has occurred approximately 7 to 8 times a year.

Conventional Parameters

Levels of alkalinity, conductivity, chlorides, dissolved solids and BOD_5 in the Bruce Channel and Howey Bay tended to be low but variable. BOD_5 levels decreased at both locations over the 1970's; in 1989 it returned to its highest level since the mid 1970's (median 0.8 mg/ℓ). The pH was variable, notably in 1985 when it ranged from 6.9 to 7.7 in Bruce Channel and from 6.6 to 8.4 in Howey Bay. Increases in alkalinity, conductivity and dissolved solids were observed during 1988-1989.

Phosphorus levels were high in the Bruce Channel during the early 1970's, but declined after 1975 to less than 0.02 mg/l. Since then levels have fluctuated at both locations; phosphorus declined over the period 1986-1988 at both locations; in 1989 it continued to decline in Howey Bay (1989 median value of .011 mg/ℓ). After initial declines in phosphorus, median levels remain relatively constant (median .011 mg/ℓ) in Bruce Channel.

Fecal coliform levels in Bruce Channel were low or absent; in Howey Bay they usually were present, at about 10 counts/100 ml.

Metals

Metals that have exceeded the PWQO's are copper, cadmium, and iron. Copper was as high as 0.05 mg/l and commonly exceeded the PWQO at both locations before 1983, since then it has remained below 0.005 mg/ℓ. Cadmium exceedances were observed in Howey Bay before 1984 and in 1985 and 1987. Cadmium was undetectable in the other four years: 1984, 1986, 1988 and 1989. Iron exceeded the PWQO in the Bruce Channel in 1979, 1980 and 1985, but has declined since 1985. Iron was low in Howey Bay (median value of 0.07 mg/ℓ) except for one exceedance of 0.46 mg/ℓ in 1980 and has been declining over the period of the record. Other metals such as lead, zinc and nickel were also low and rarely exceeded PWQO's. There was a general decline in levels of metals in the late 1980's.

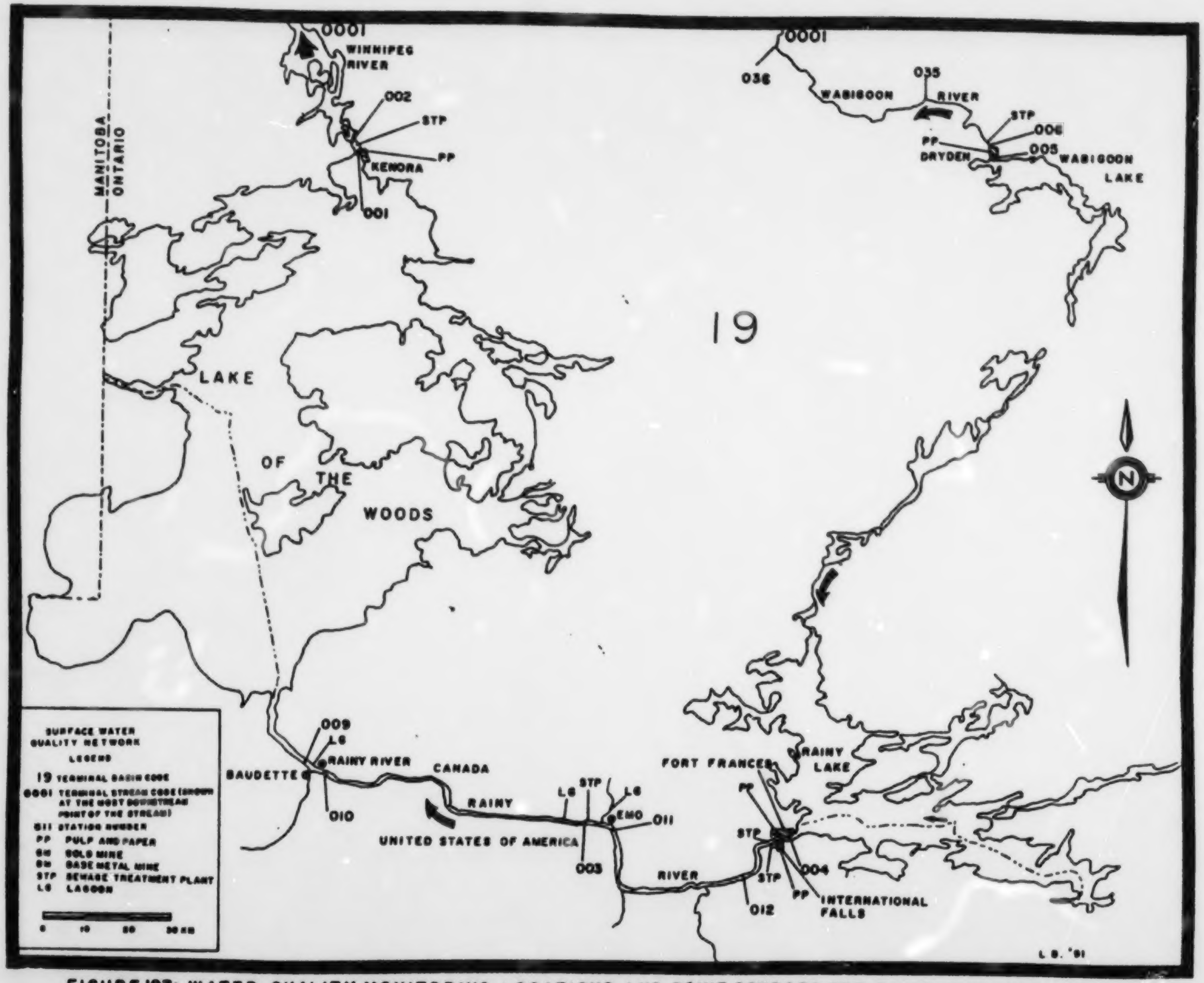

0001
WINNIPEG RIVER
002
STP
PP
KENORA
001
MANITOBA
ONTARIO
LAKE OF THE WOODS
0001
036
WABIGOON RIVER
035
STP
006
PP
DRYDEN
005
WABIGOON LAKE
19
N
009
LG
RAINY RIVER
BAUDETTE
010
CANADA
RAINY RIVER
UNITED STATES OF AMERICA
LG
STP
LG
EMO
011
003
FORT FRANCES
RAINY LAKE
PP
STP
STP
004
PP
012
INTERNATIONAL FALLS
L.B. '91
SURFACE WATER QUALITY NETWORK
LEGEND
19 TERMINAL BASIN CODE
0001 TERMINAL STREAM CODE (SHOWN AT THE MOST DOWNSTREAM POINT OF THE STREAM)
011 STATION NUMBER
PP PULP AND PAPER
GM GOLD MINE
BM BASE METAL MINE
STP SEWAGE TREATMENT PLANT
LG LAGOON
0
10
20
30 KM

FIGURE 107: WATER QUALITY MONITORING LOCATIONS AND POINT SOURCES FOR RAINY, WINNIPEG, AND WABIGOON RIVER IN NORTHWESTERN ONTARIO.

Table 7 Selected water quality parameters (median values) in the Wabigoon River.

Station	Flow* m^3/s	BOD mg/ℓ	Chlorides mg/ℓ	Conductivity µS	DO mg/ℓ	pH	Suspended Solids mg/ℓ	Total Phosphorus mg/ℓ	Total Ammonia mg/ℓ	Aluminum mg/ℓ	Cadmium mg/ℓ	Copper mg/ℓ	Zinc mg/ℓ	Iron mg/ℓ	Mercury HGUT µg/ℓ
U/S Pulp Mill -0001-0005-	-	0.9	1.4	105	10.6	7.6	5	0.032	0.44	0.96 limited data	< limited data	0.003	0.004	0.81	<
Golf Course Bridge -0001-006-	10.9	9.2	25.5	234	9.0	7.4	15	0.077	0.64	1.04	<	0.005	0.009	0.94	0.009
Minnitaki Rd. -0001-035-	-	2.3	37.0	284	7.0	7.2	10	0.079	0.73	0.96	0.0002	0.004	0.008	0.87	0.021
Quibell -0001-036-	-	1.4	20.5	194	9.3	7.3	7	0.051	0.59	0.48	0.0002	0.003	0.004	0.63	0.017

BOD_5 - biological oxygen demand
DO - dissolved oxygen
< - below detection limits
* - annual mean discharge (Environmental Canada 1989)

Table 8   Selected water quality parameters (long term median values) in the Rainy River.

Station mg/ℓ	BOD mg/ℓ	Dissolved Oxygen mg/ℓ	Conductivity mg/ℓ	Suspended Solids mg/ℓ	Total Phosphorus mg/ℓ	Total Coliform #/100 ml	Fecal Coliform #/100 ml
U/S Fort Frances -0001-004-	0.7	10.0	54	3	0.018	140	1
D/S Fort Frances -0001-012-	1.2	9.2	66	5	0.030	4200	400
U/S Emo -0001-011-	1.0	9.0	77	6	0.036	3800	200
D/S Emo -0001-003-	1.0	9.0	75	7	0.037	2700	190
U/S Baudette -0001-010-	1.0	9.0	90	5	0.034	1300	40
D/S Baudette -0001-009-	1.0	9.4	87	6	0.036	1500	60

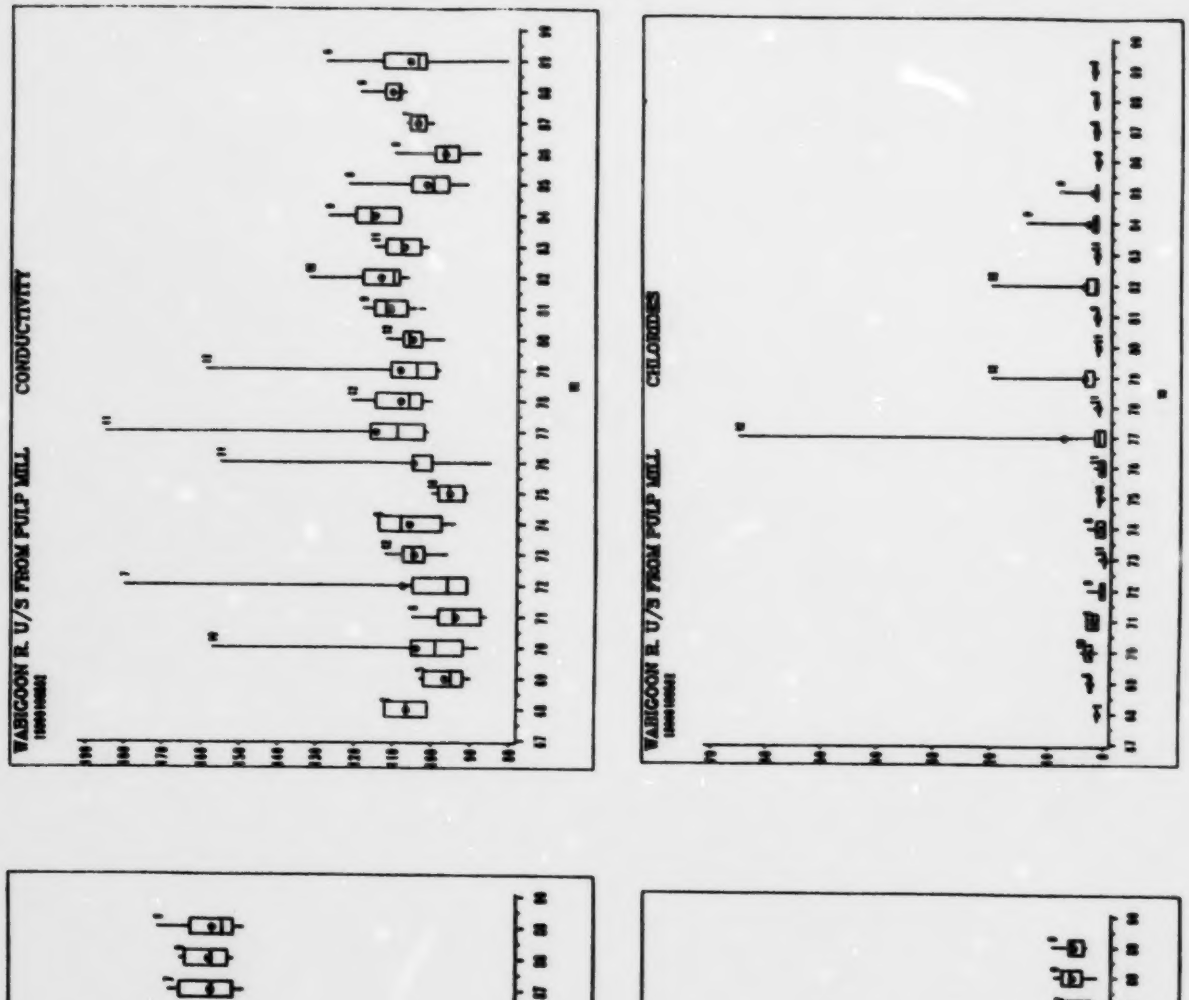


Fig. 108. Water quality in Wabigoon River at U/S pulp mill.

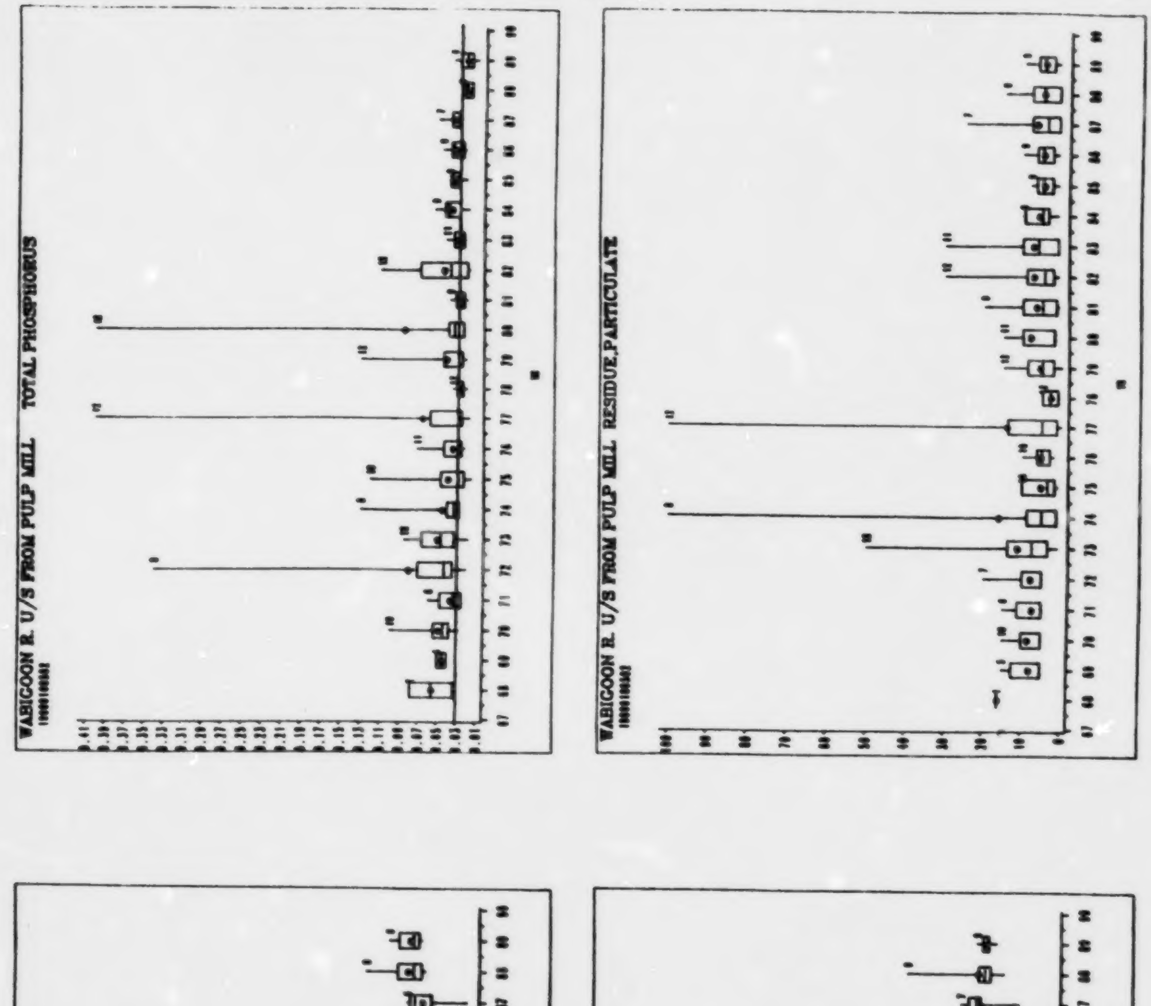


Fig. 109. Water quality in Wabigoon River at U/S pulp mill.

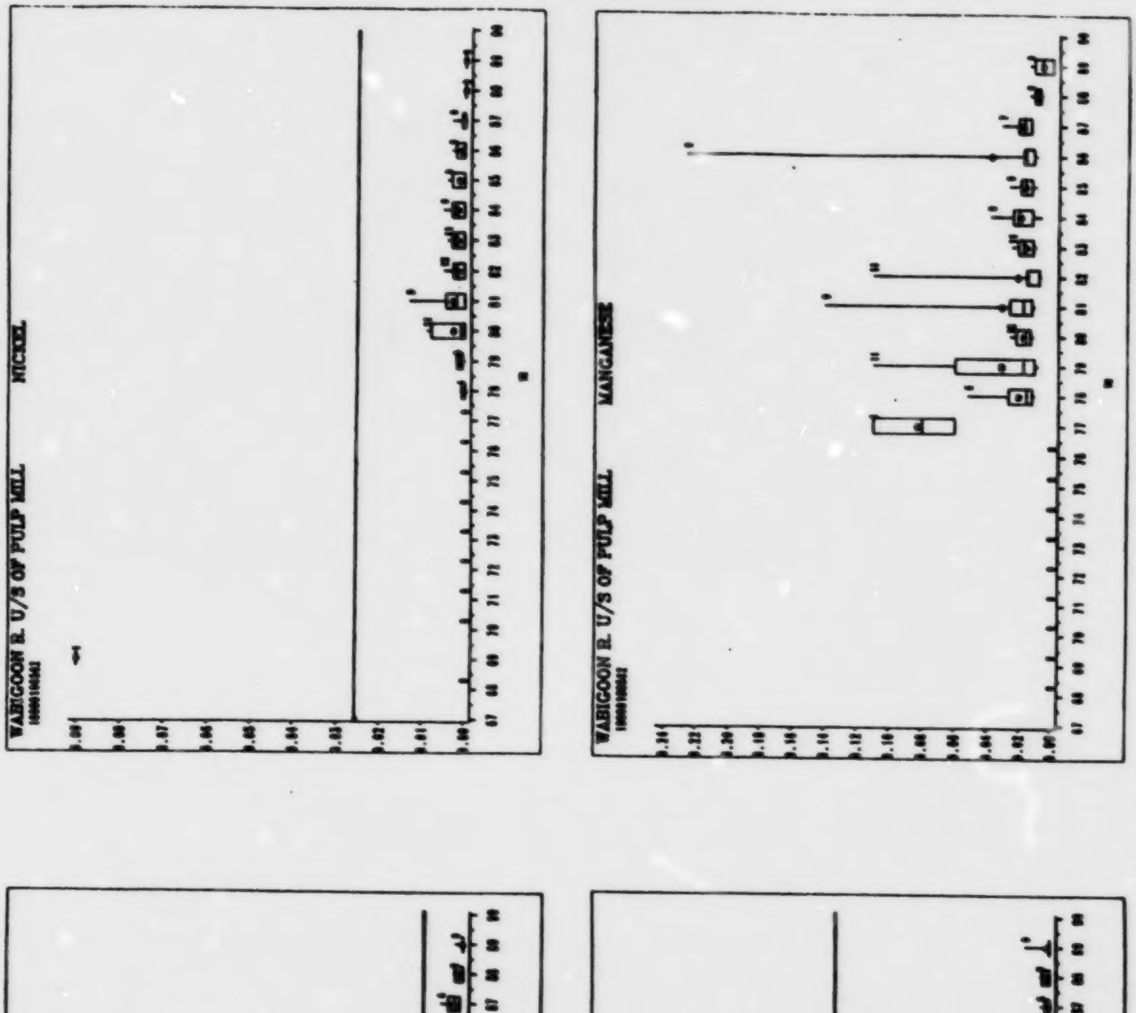


Fig. 110. Water quality in Wabigoon River at U/S pulp mill.

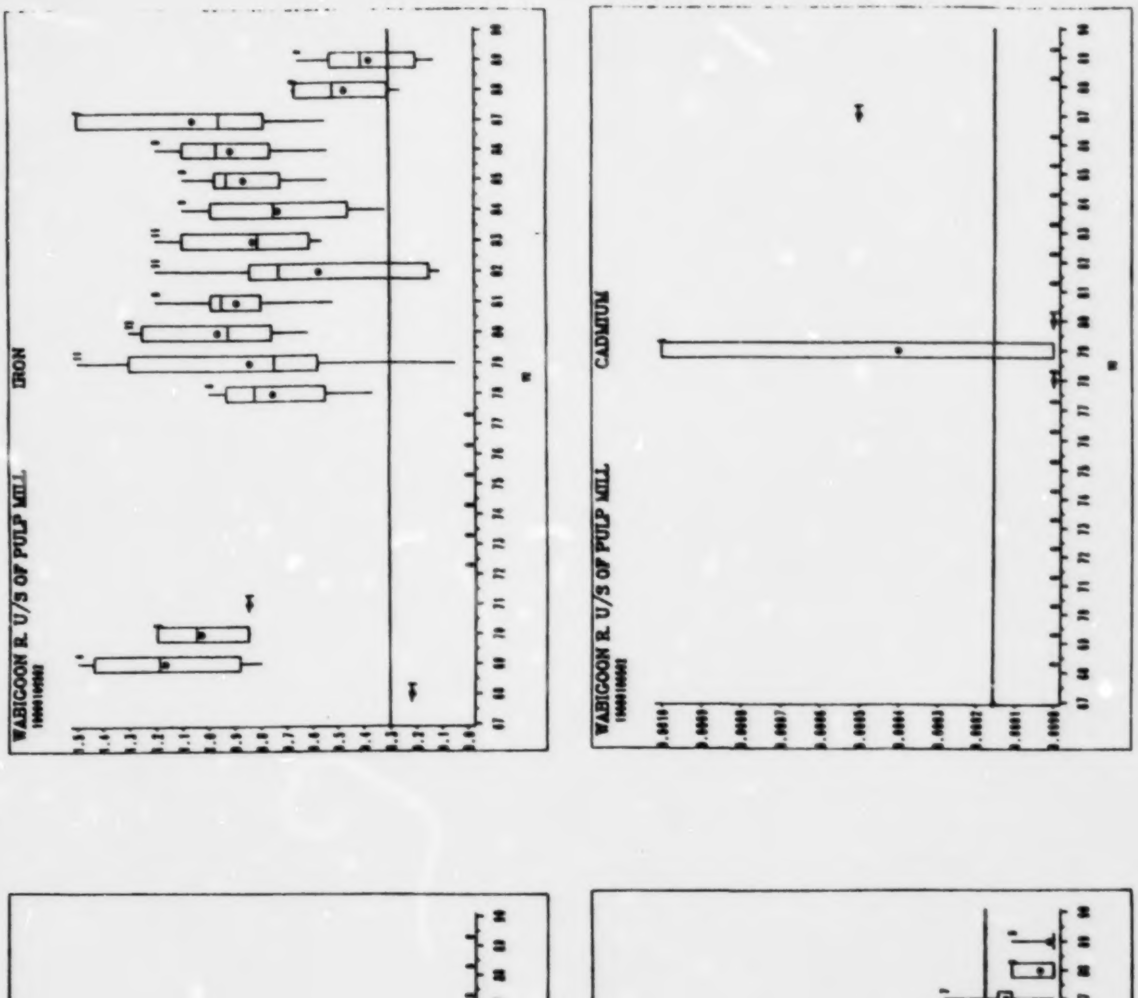


Fig. 111. Water quality in Wabigoon River at U/S pulp mill.

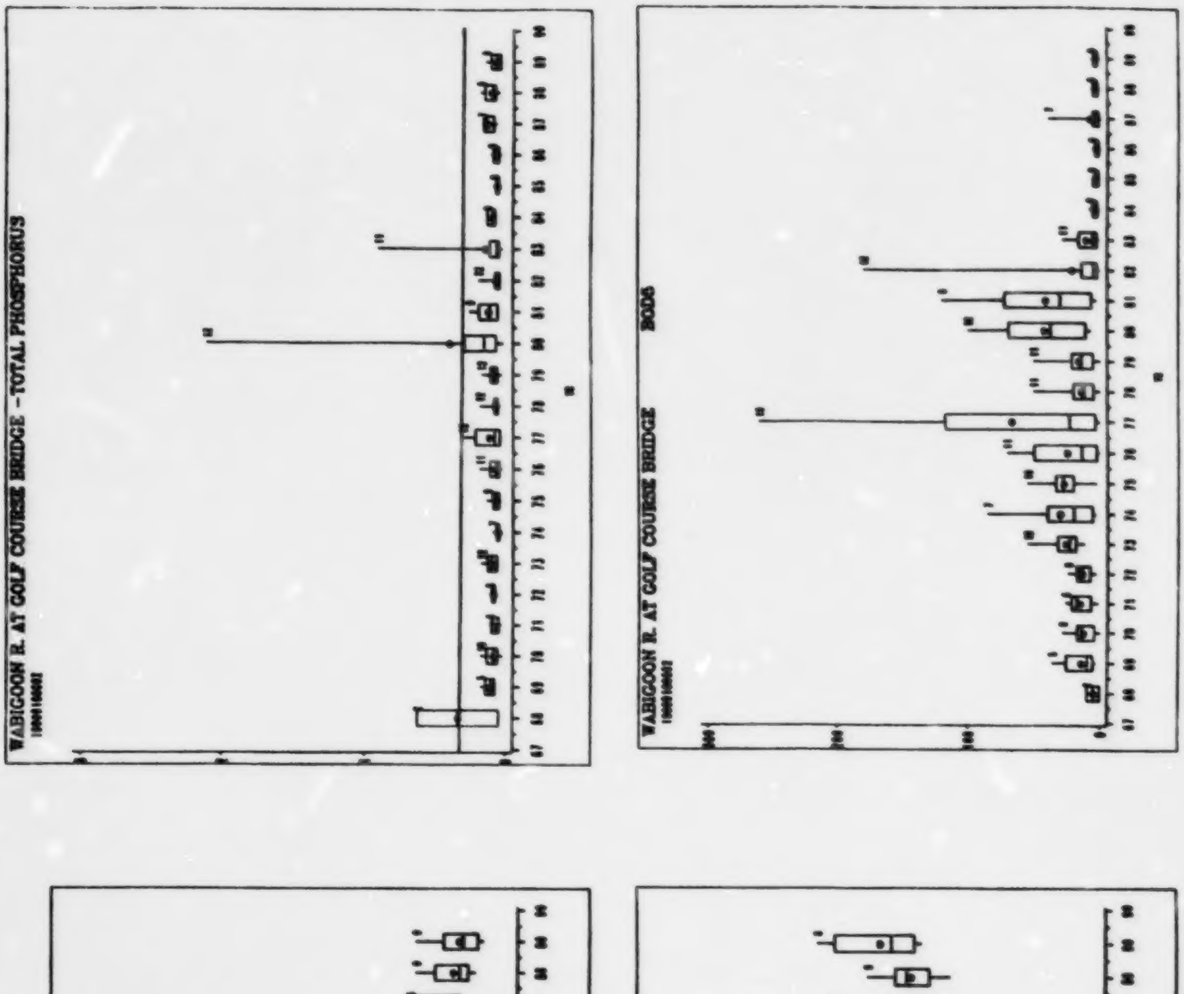


Fig. 112. Water quality in Wabigoon River at golf course bridge

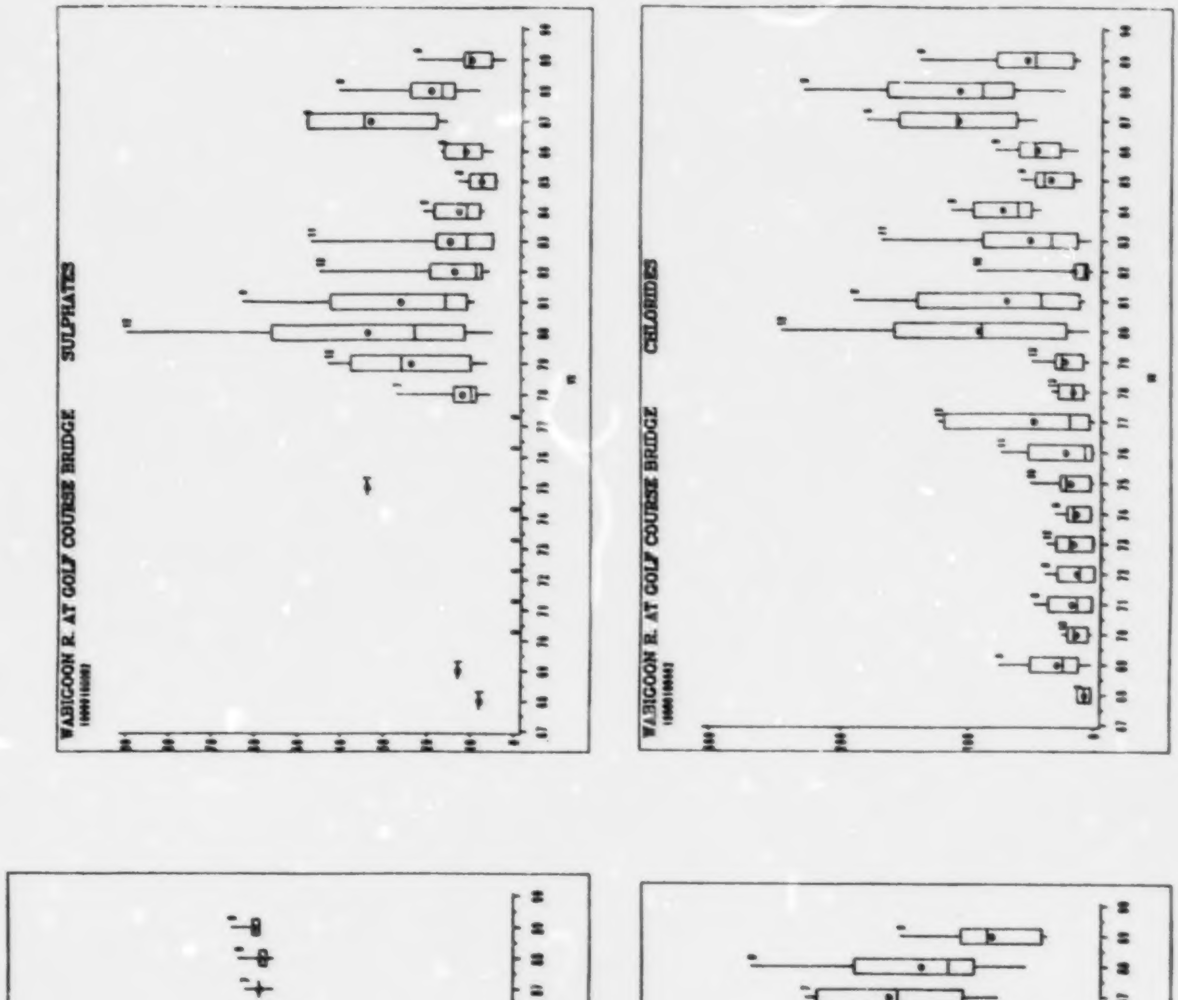


Fig. 113. Water quality in Wabigoon River at golf course bridge.

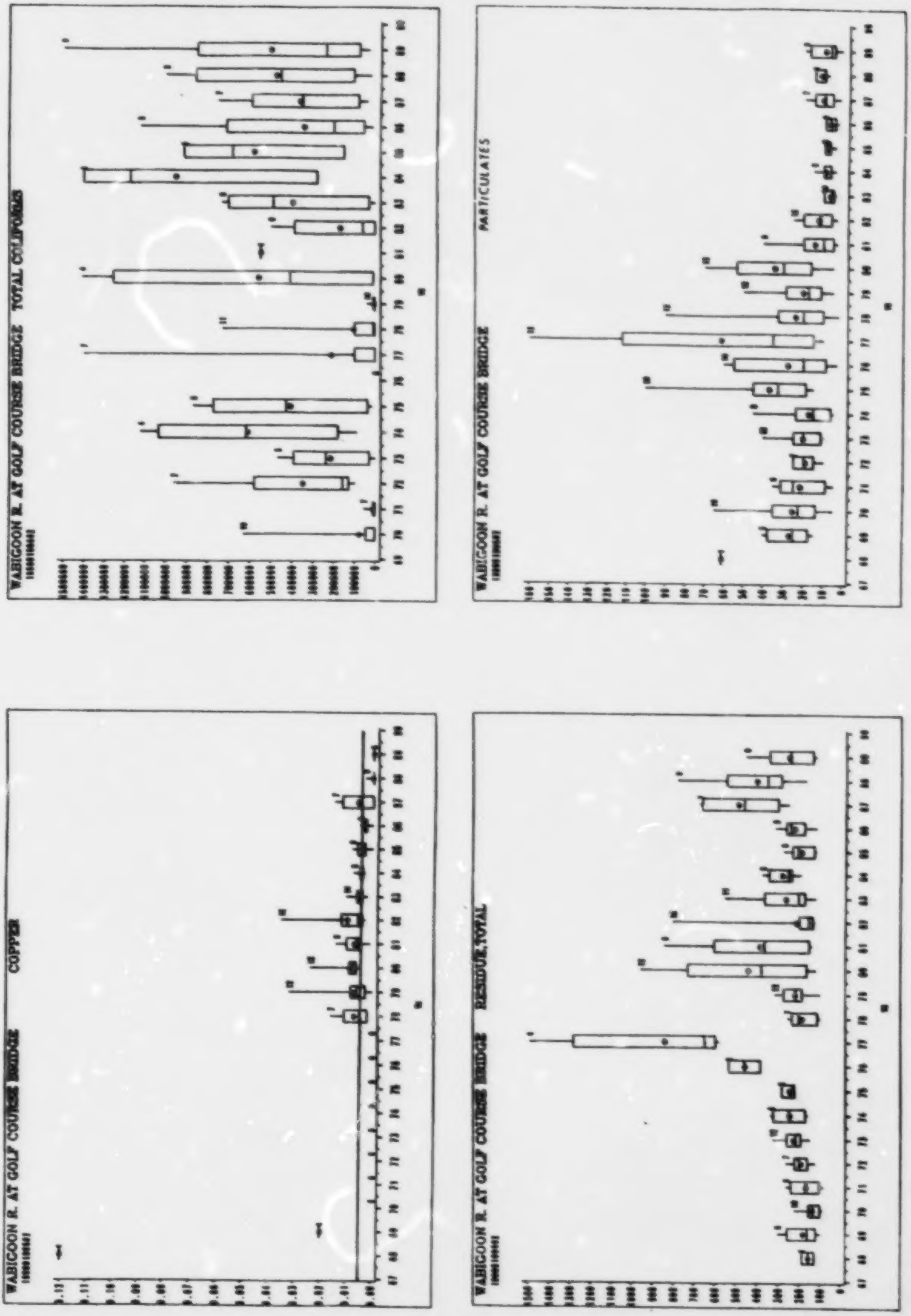


Fig. 114. Water quality in Wabigoon River at golf course bridge.

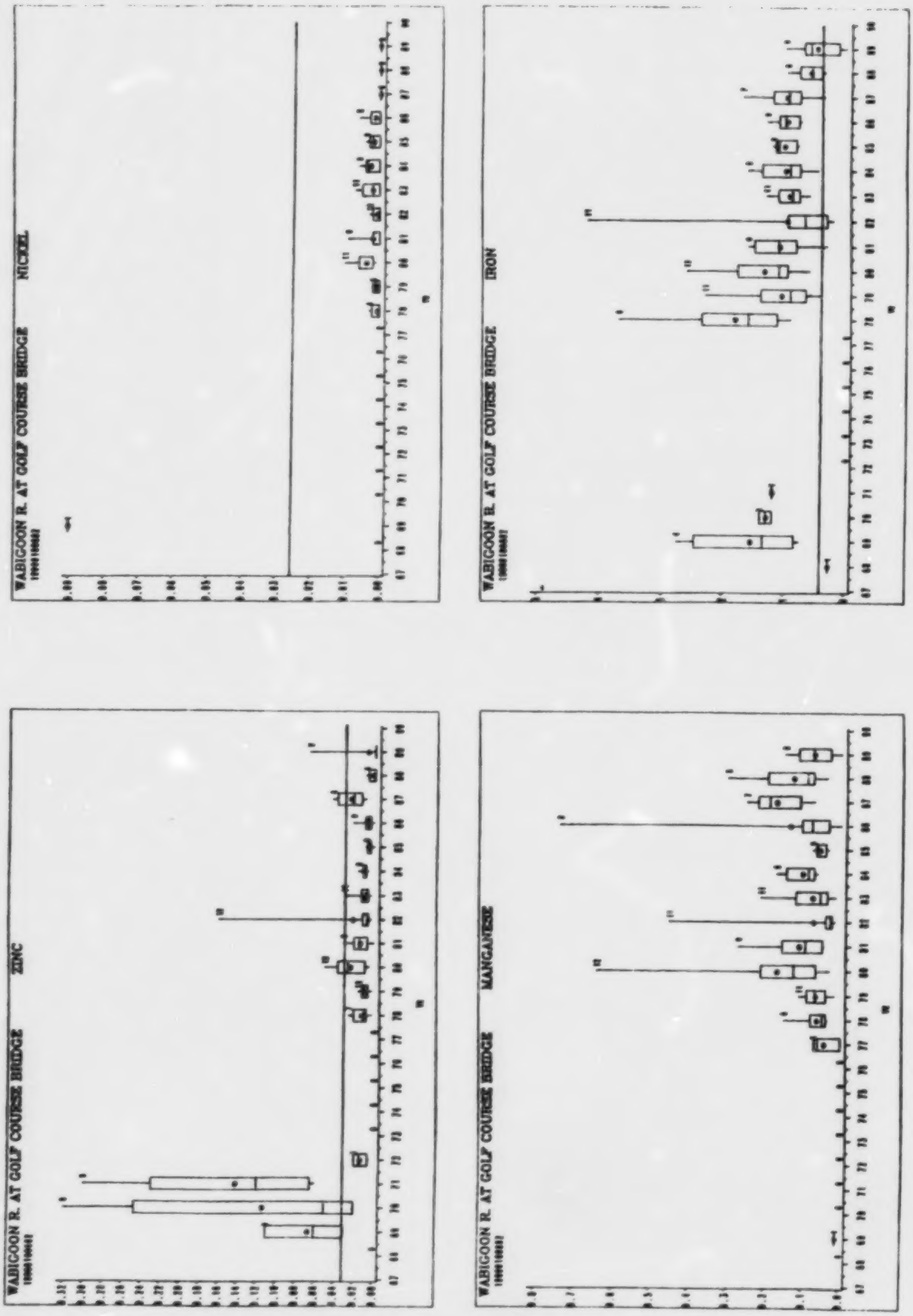


Fig. 115. Water quality in Wabigoon River at golf course bridge.

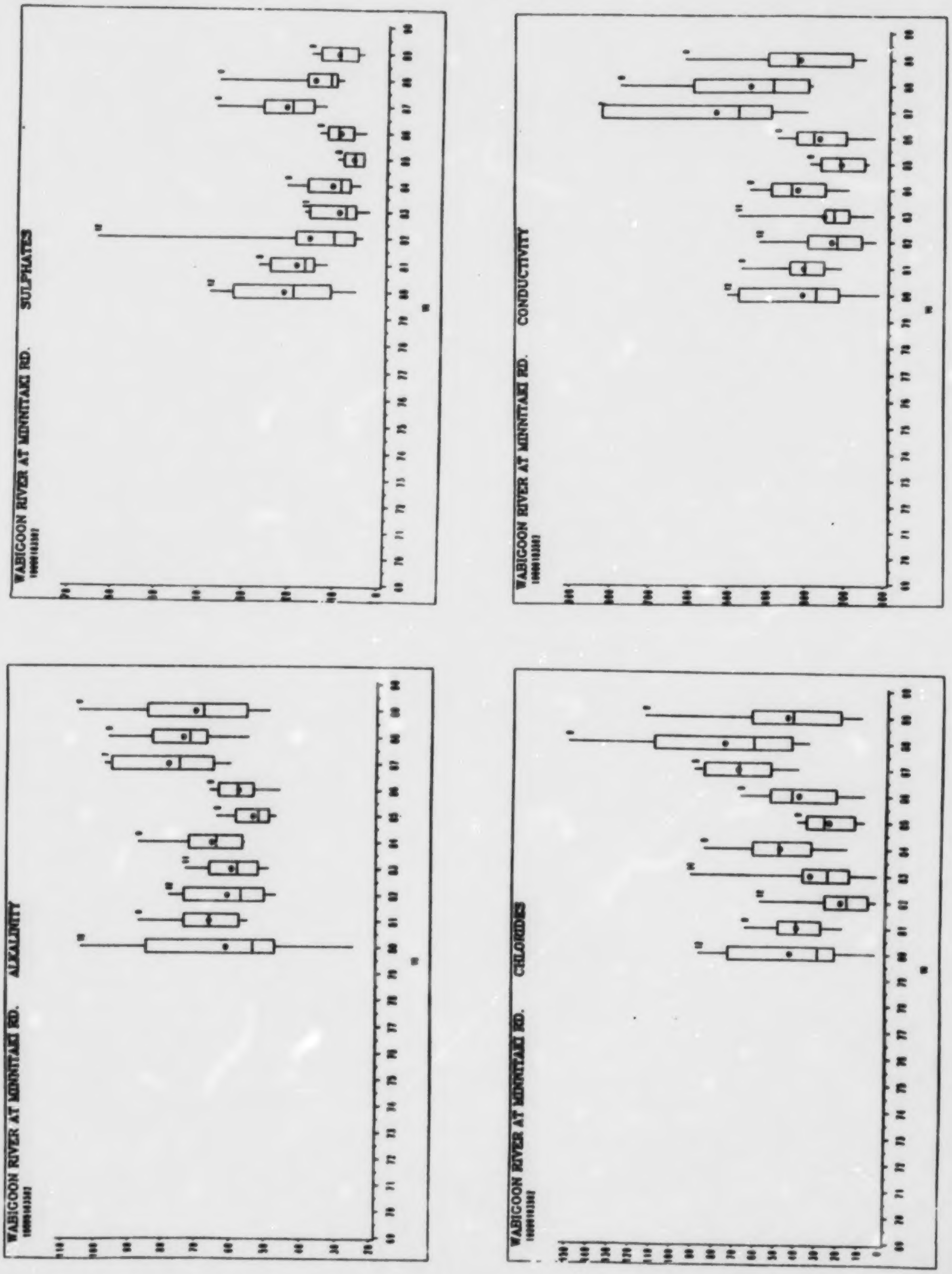


Fig. 116. Water quality in Wabigoon River at Minnitaki Road.

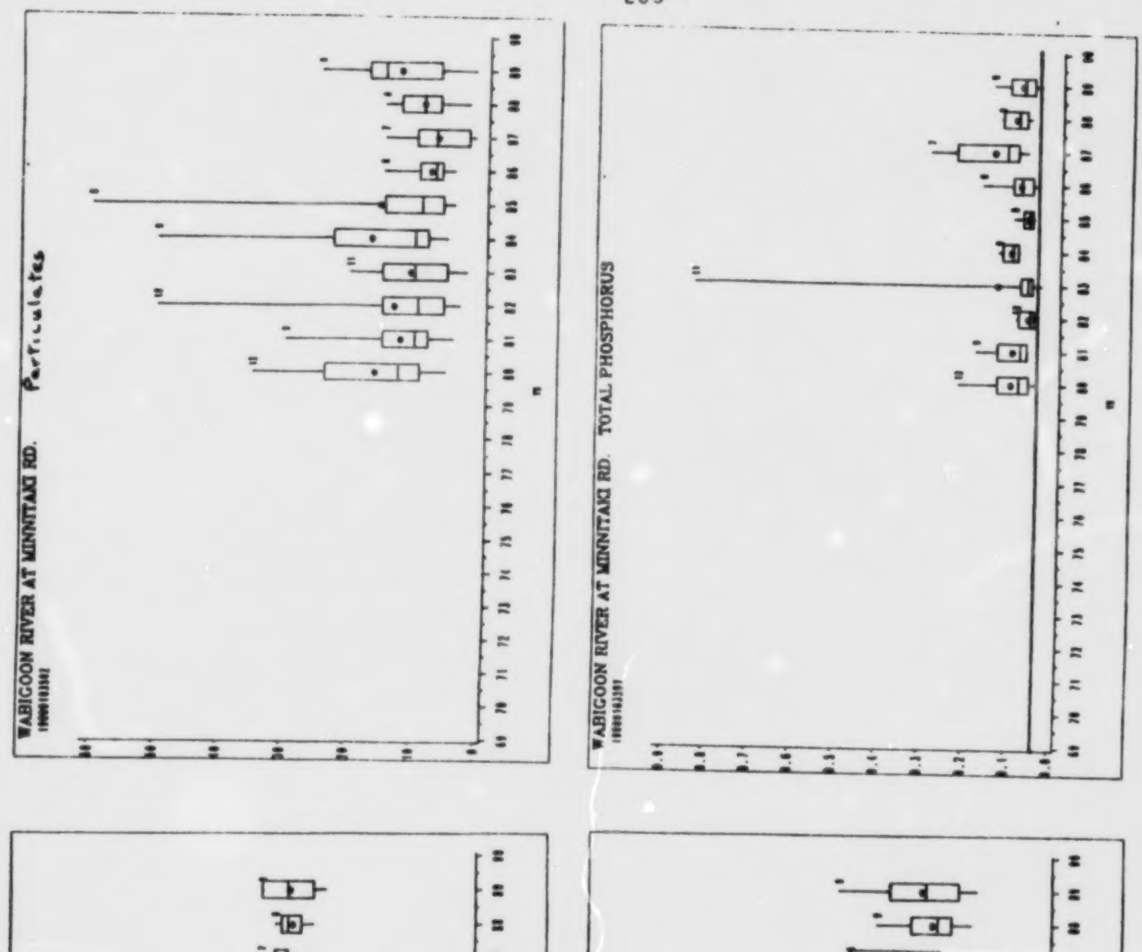


Fig. 117. Water quality in Wabigoon River at Minnitaki Road.

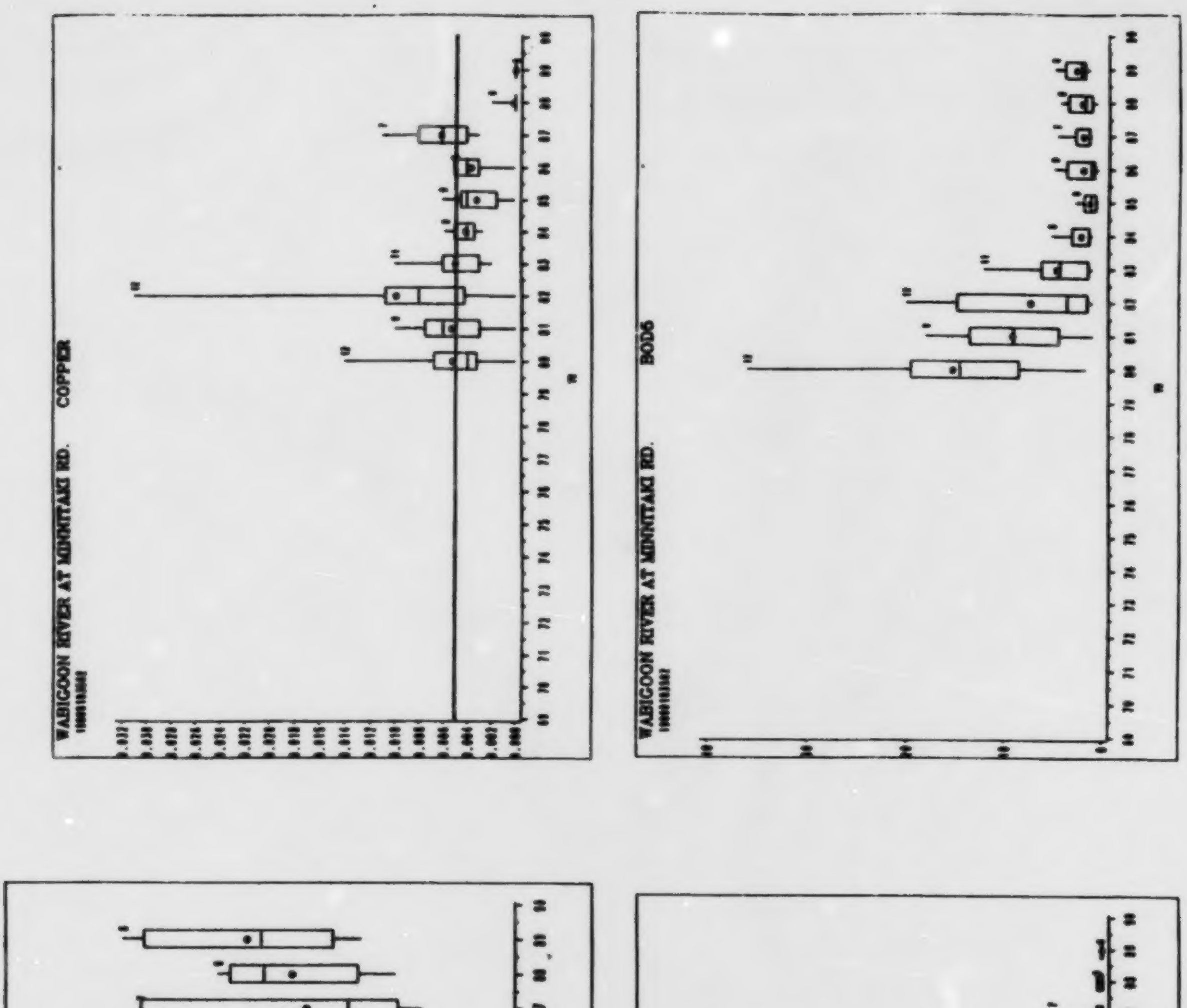


Fig. 118. Water quality in Wabigoon River at Minnitaki Road.

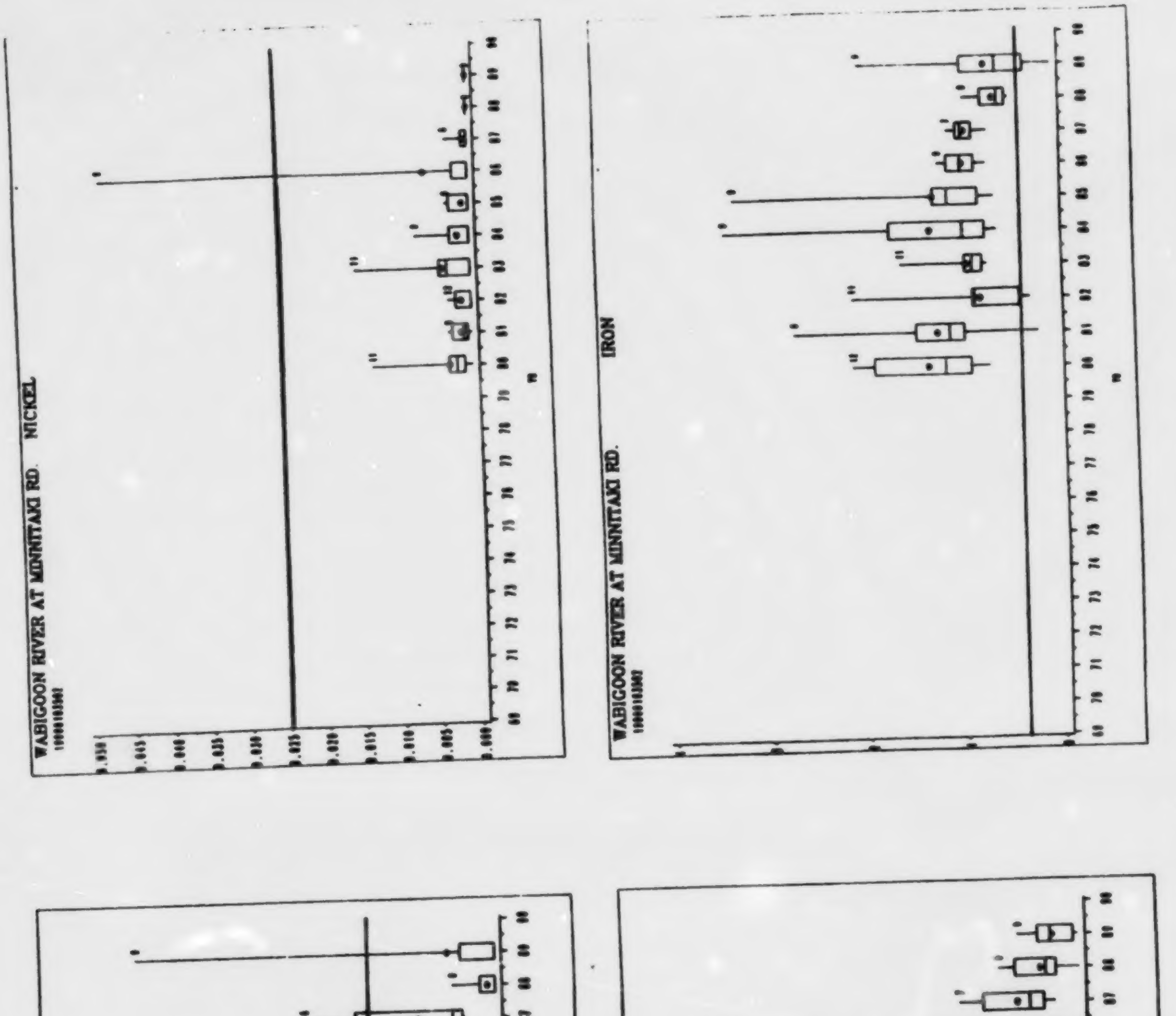


Fig. 119. Water quality in Wabigoon River at Minnitaki Road.

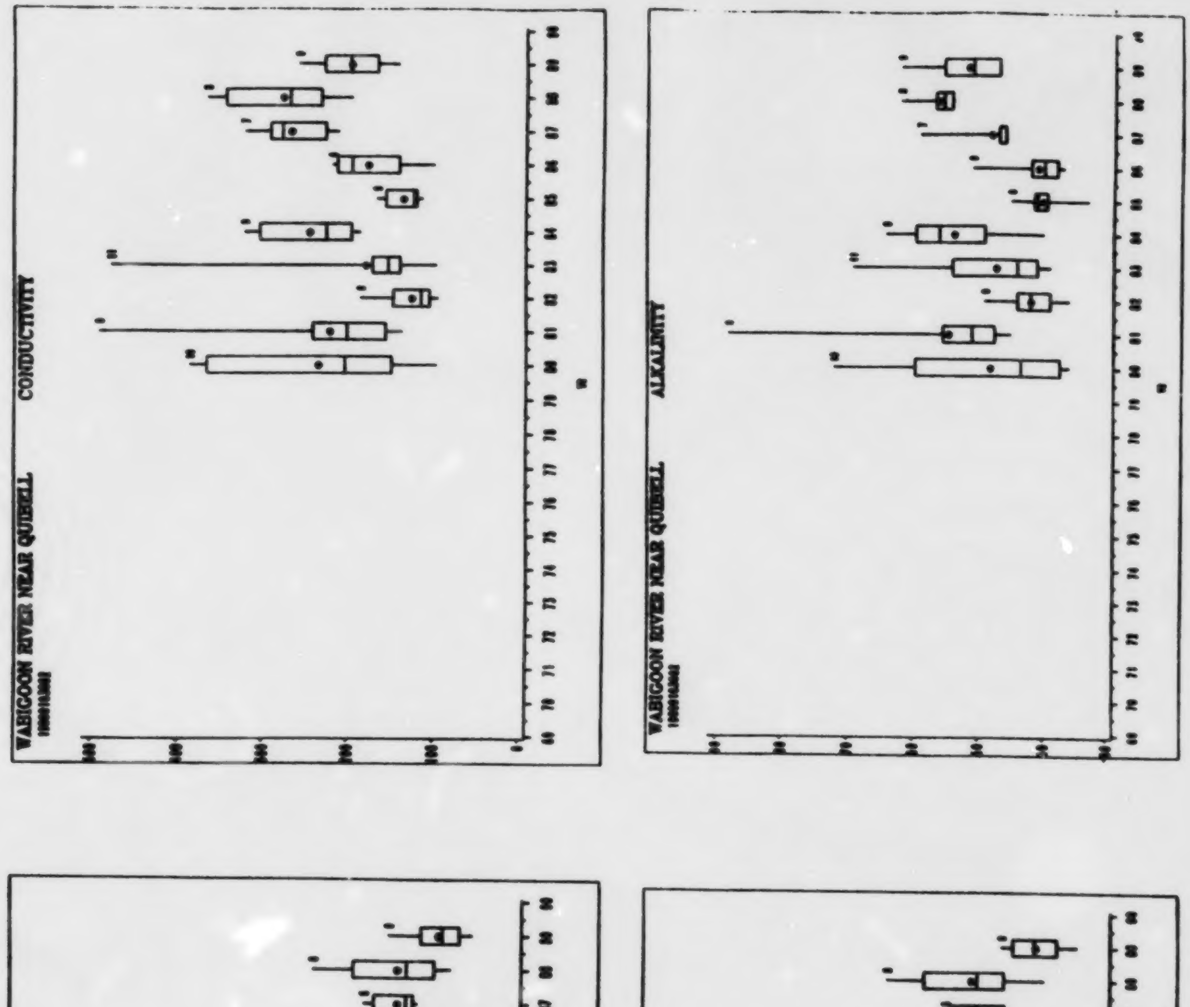


Fig. 120. Water quality in Wabigoon River near Quibell.

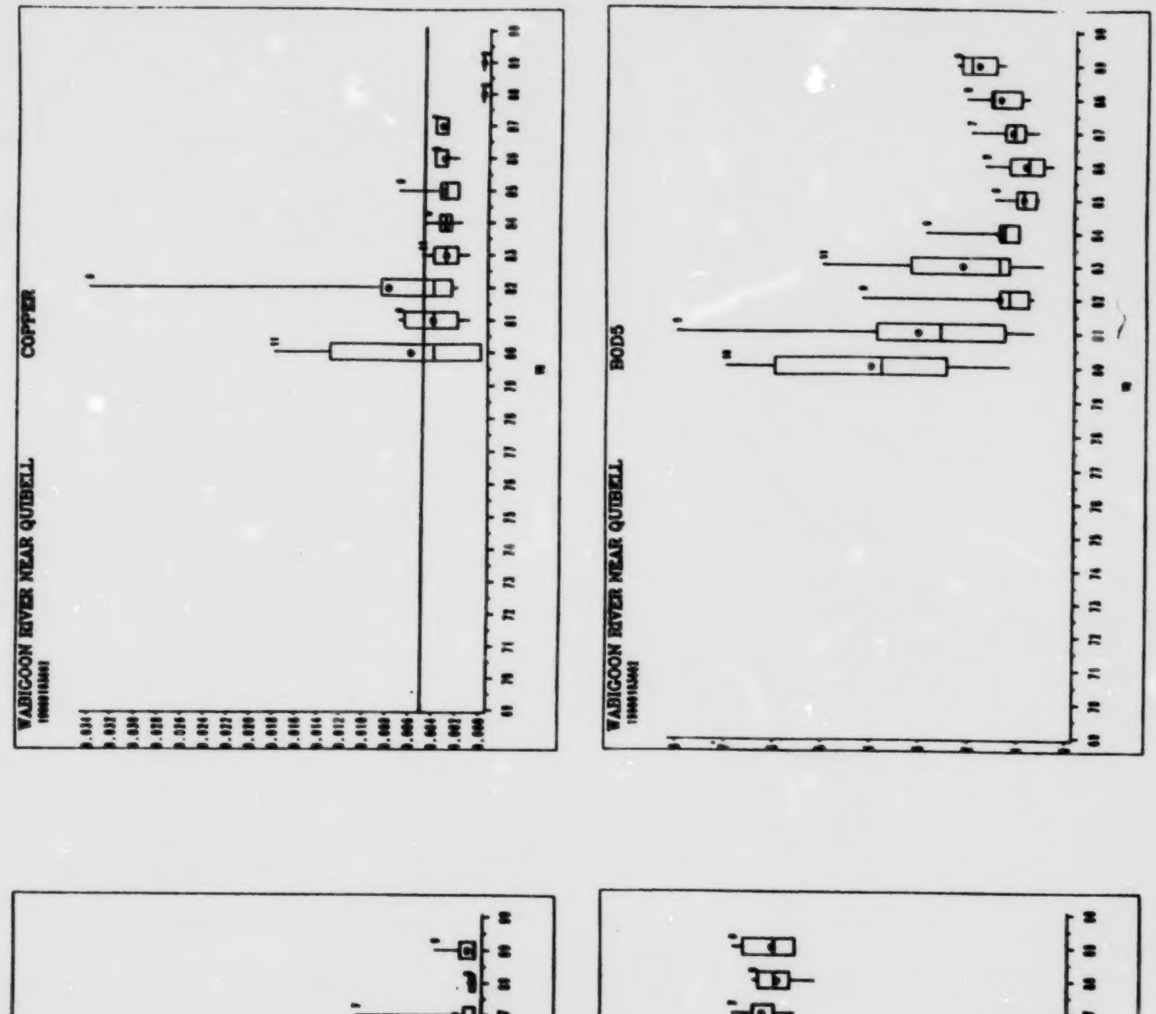


Fig. 121. Water quality in Wabigoon River near Quibell.

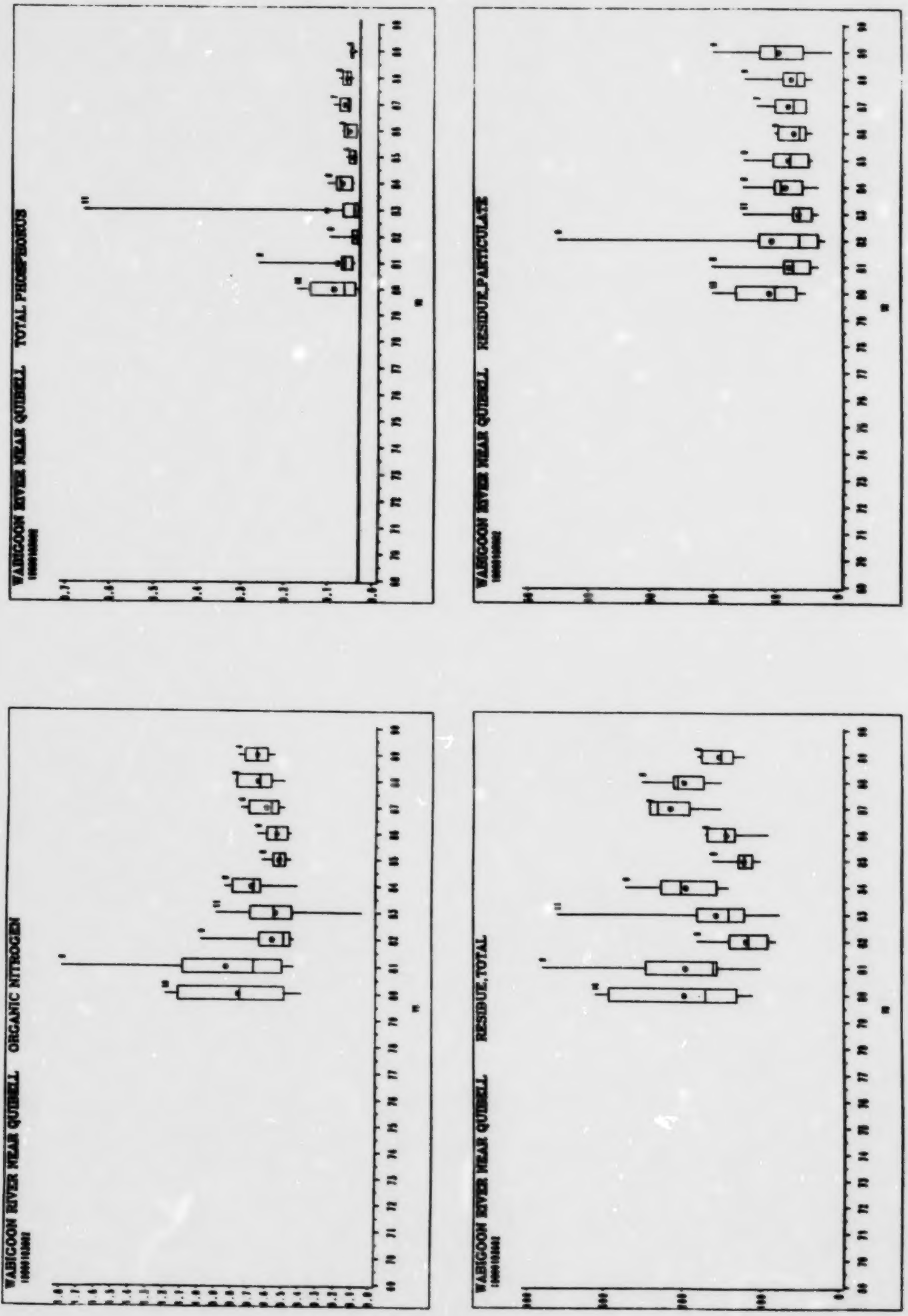


Fig. 122. Water quality in Wabigoon River near Quibell.

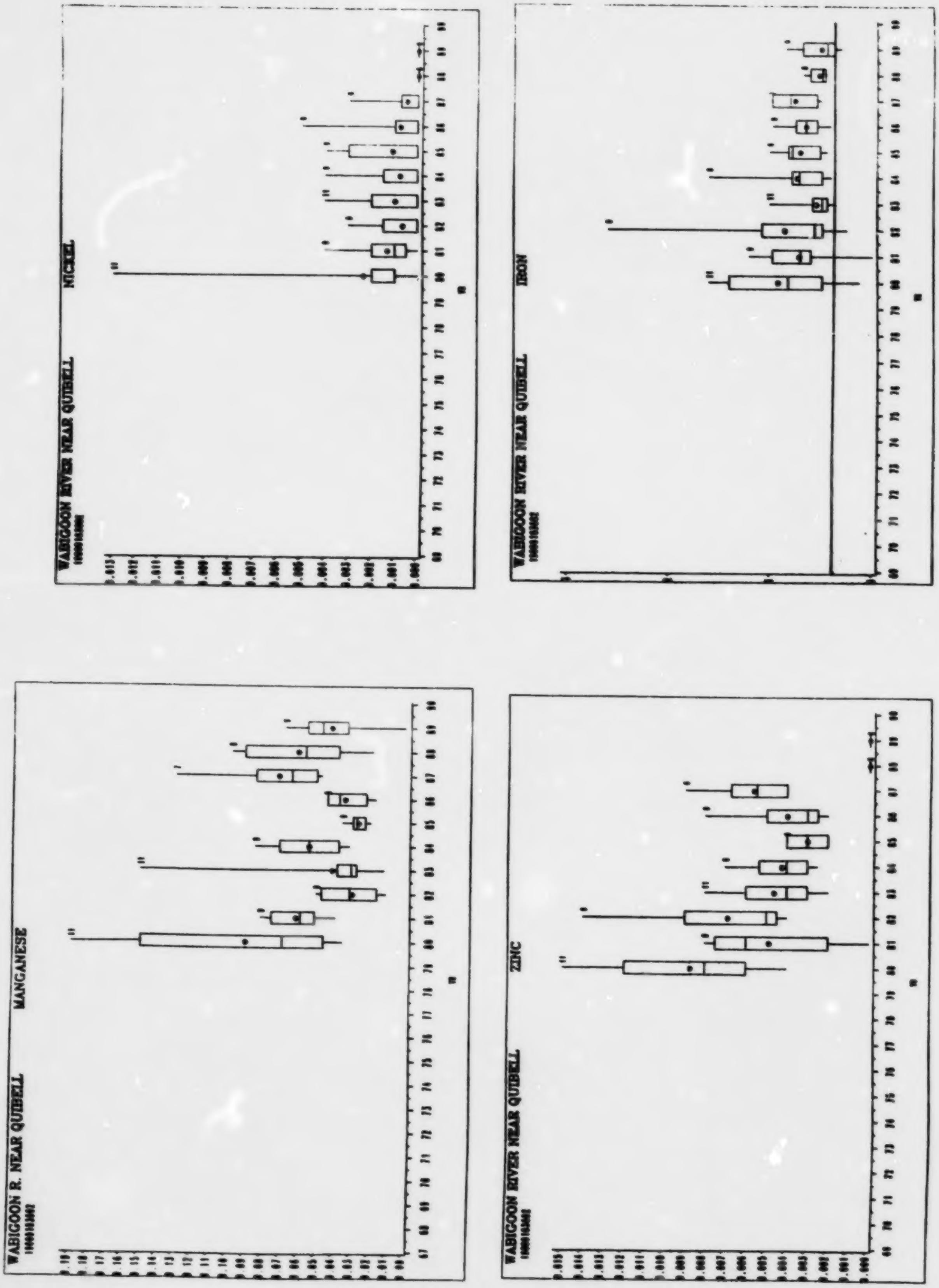


Fig. 123. Water quality in Wabigoon River near Quibell.

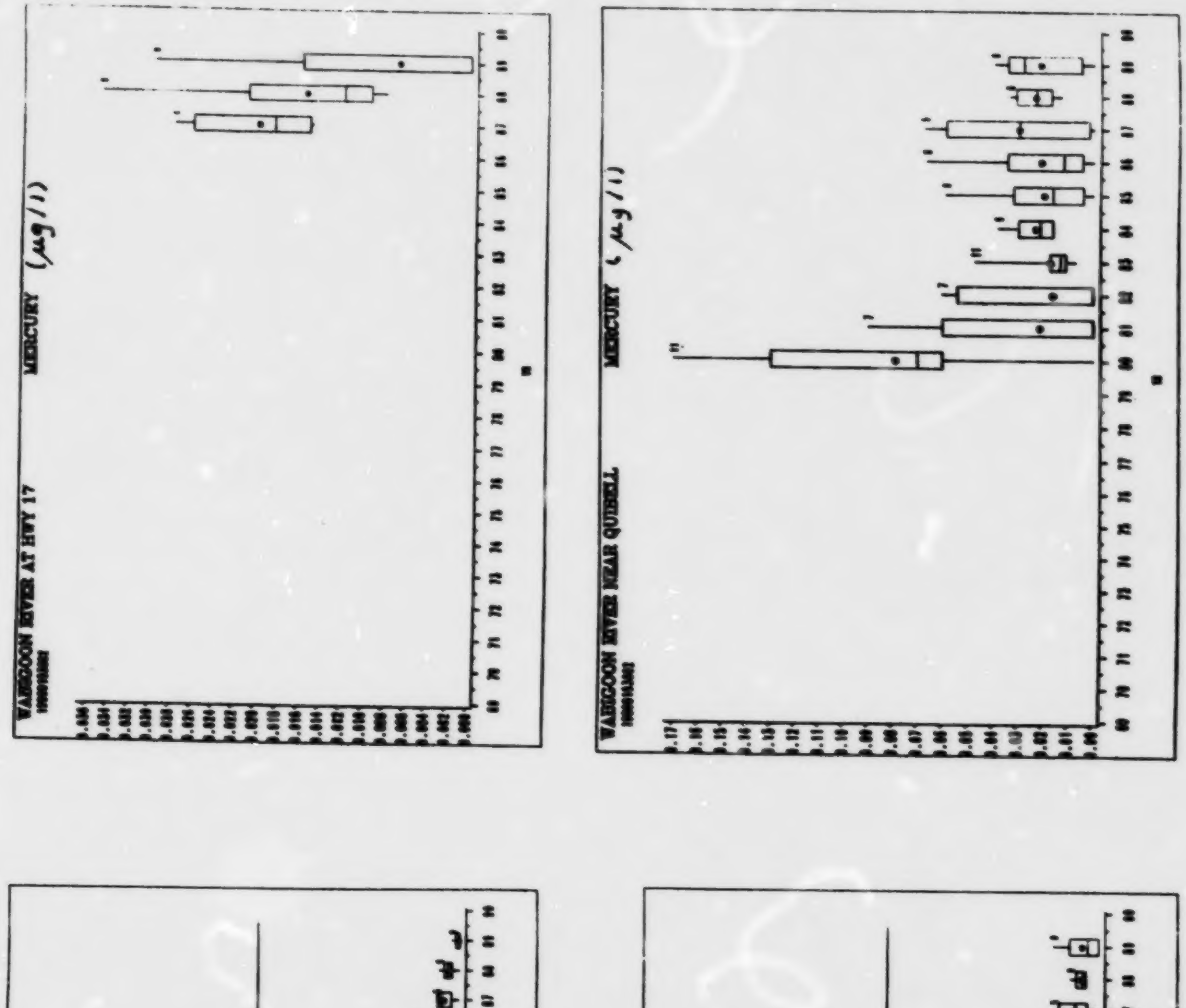


Fig. 124. Water quality in Wabigoon River near Quibell.

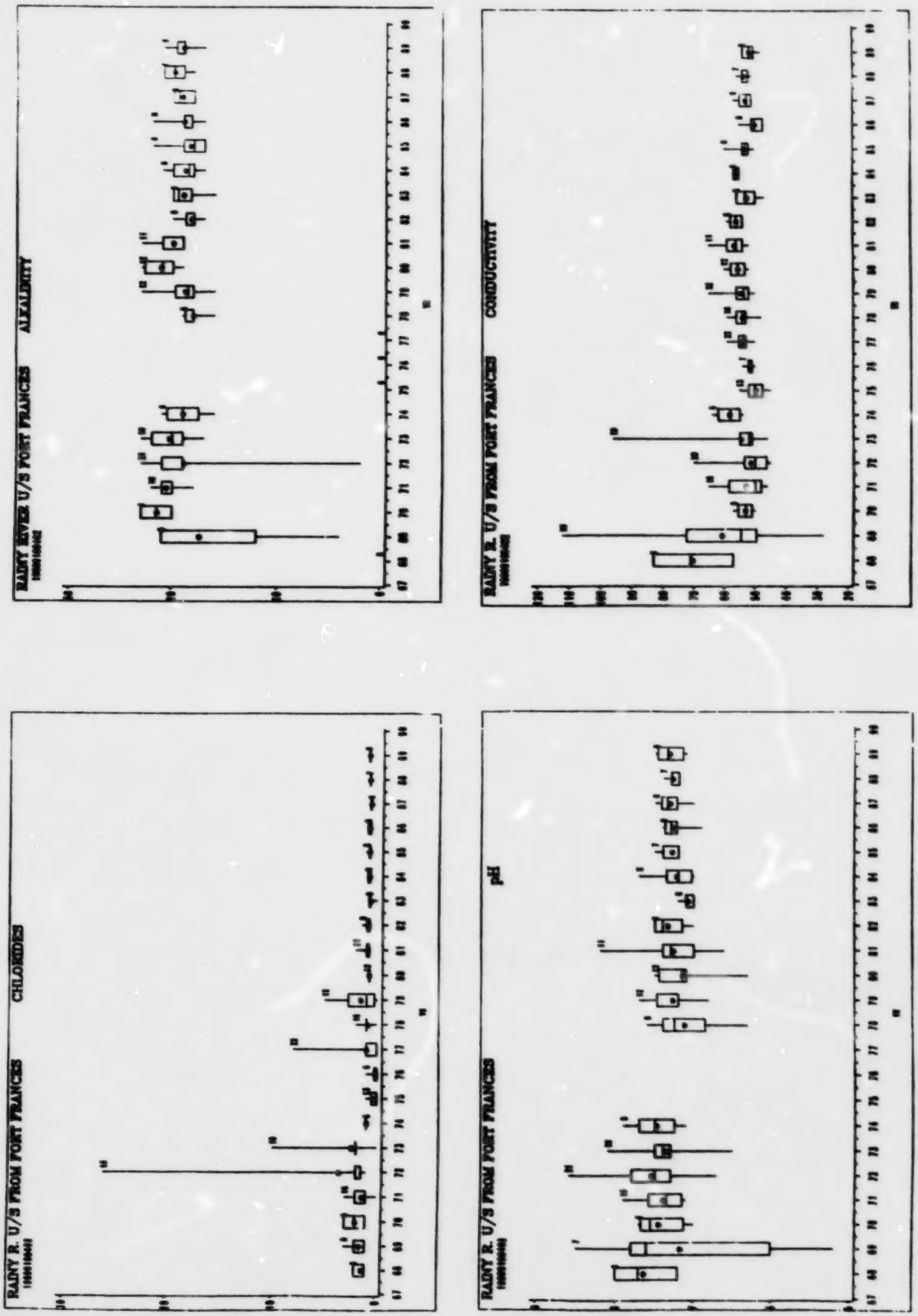


Fig. 125. Water quality in Rainy River U/S Fort Frances.

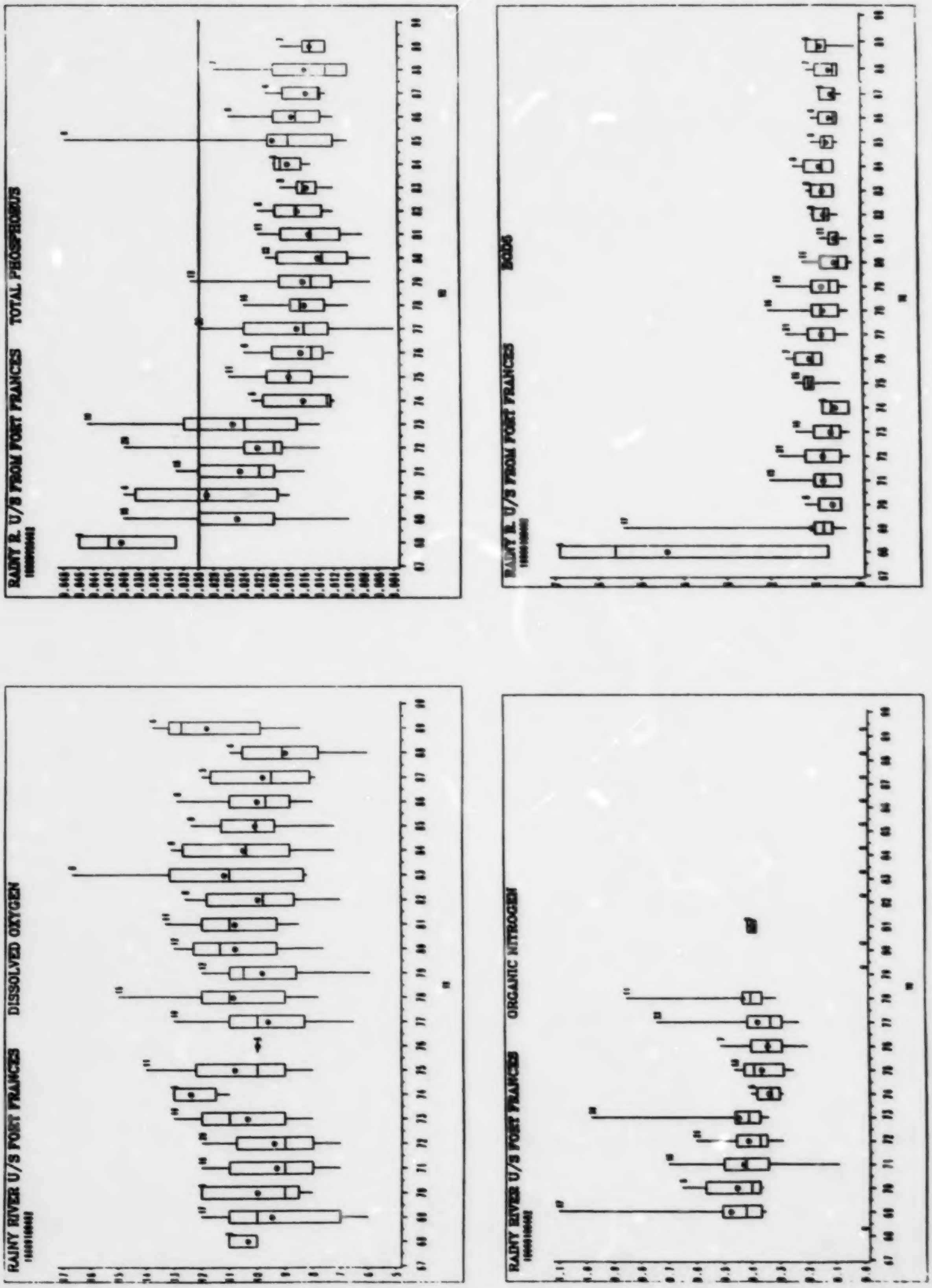


Fig. 126. Water quality in Rainy River U/S Fort Frances.

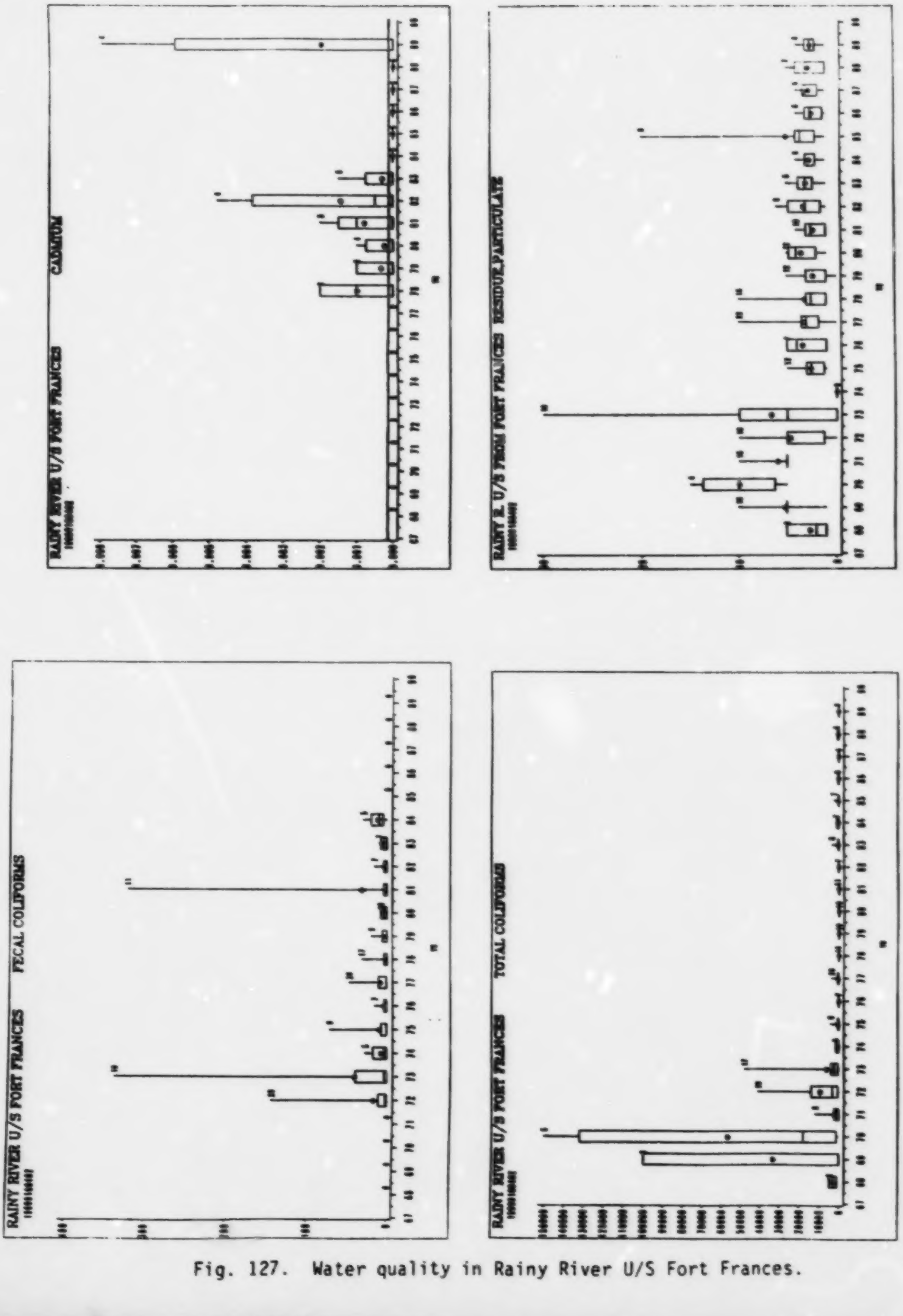


Fig. 127. Water quality in Rainy River U/S Fort Frances.

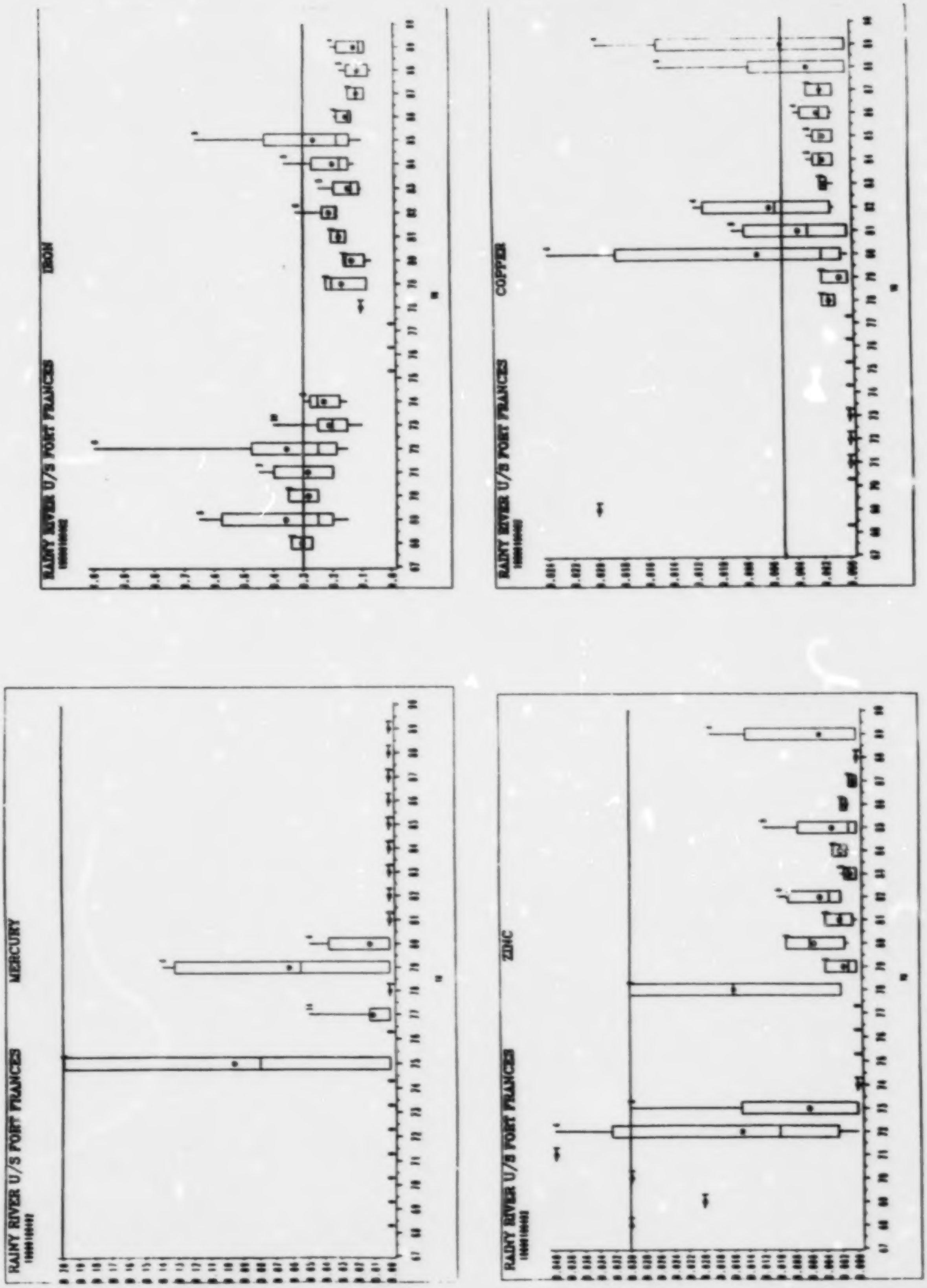


Fig. 128. Water quality in Rainy River U/S Fort Frances.

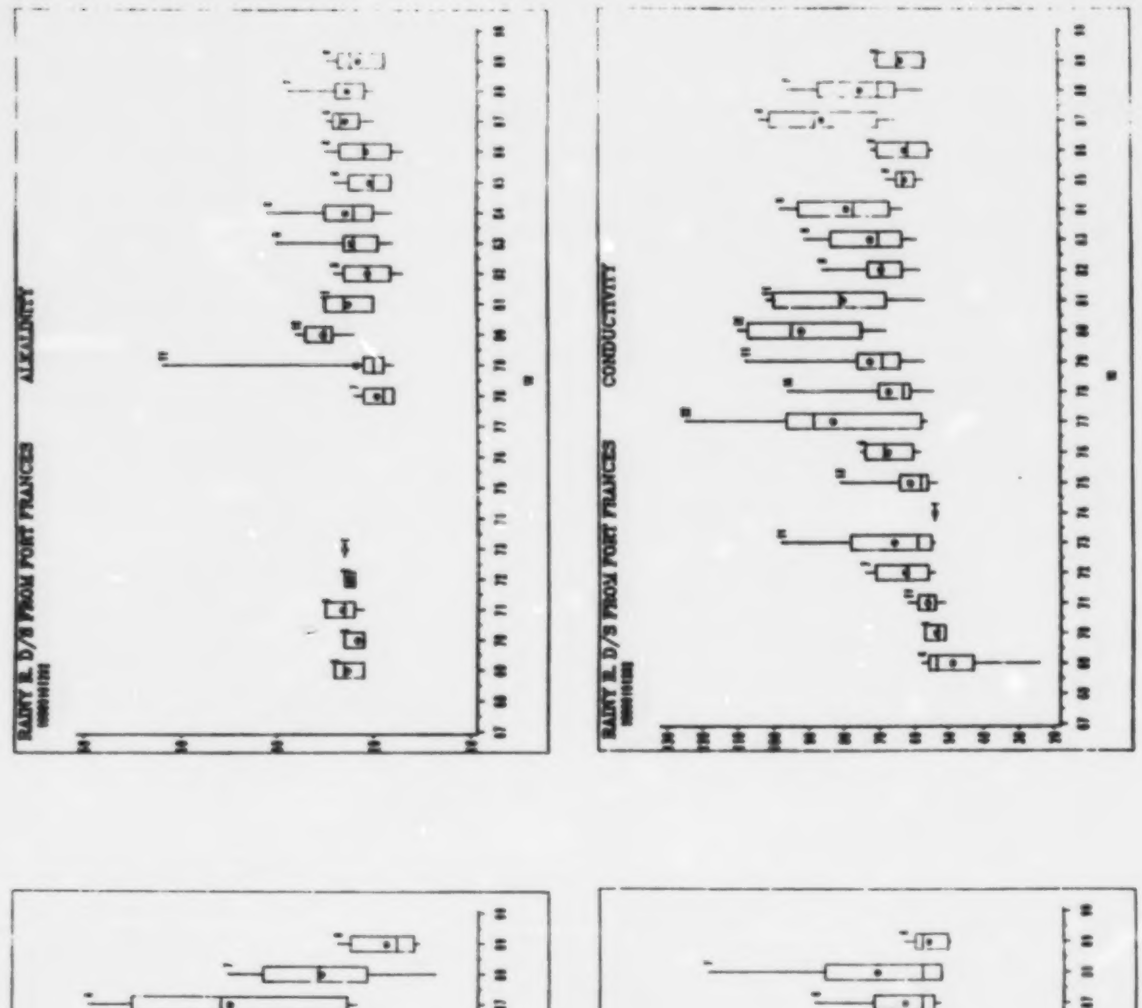


Fig. 129. Water quality in Rainy River D/S Fort Frances.

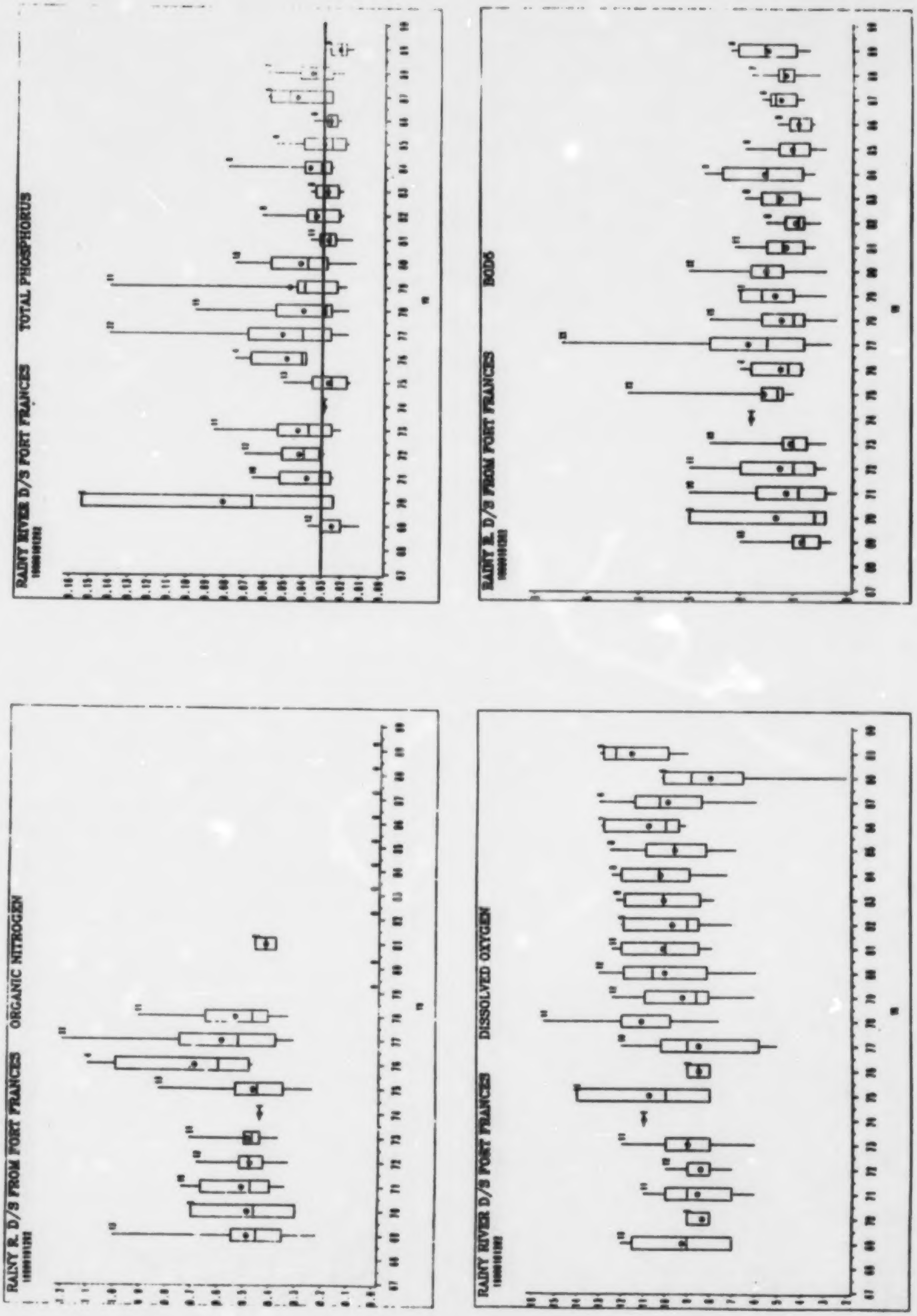


Fig. 130. Water quality in Rainy River D/S Fort Frances.

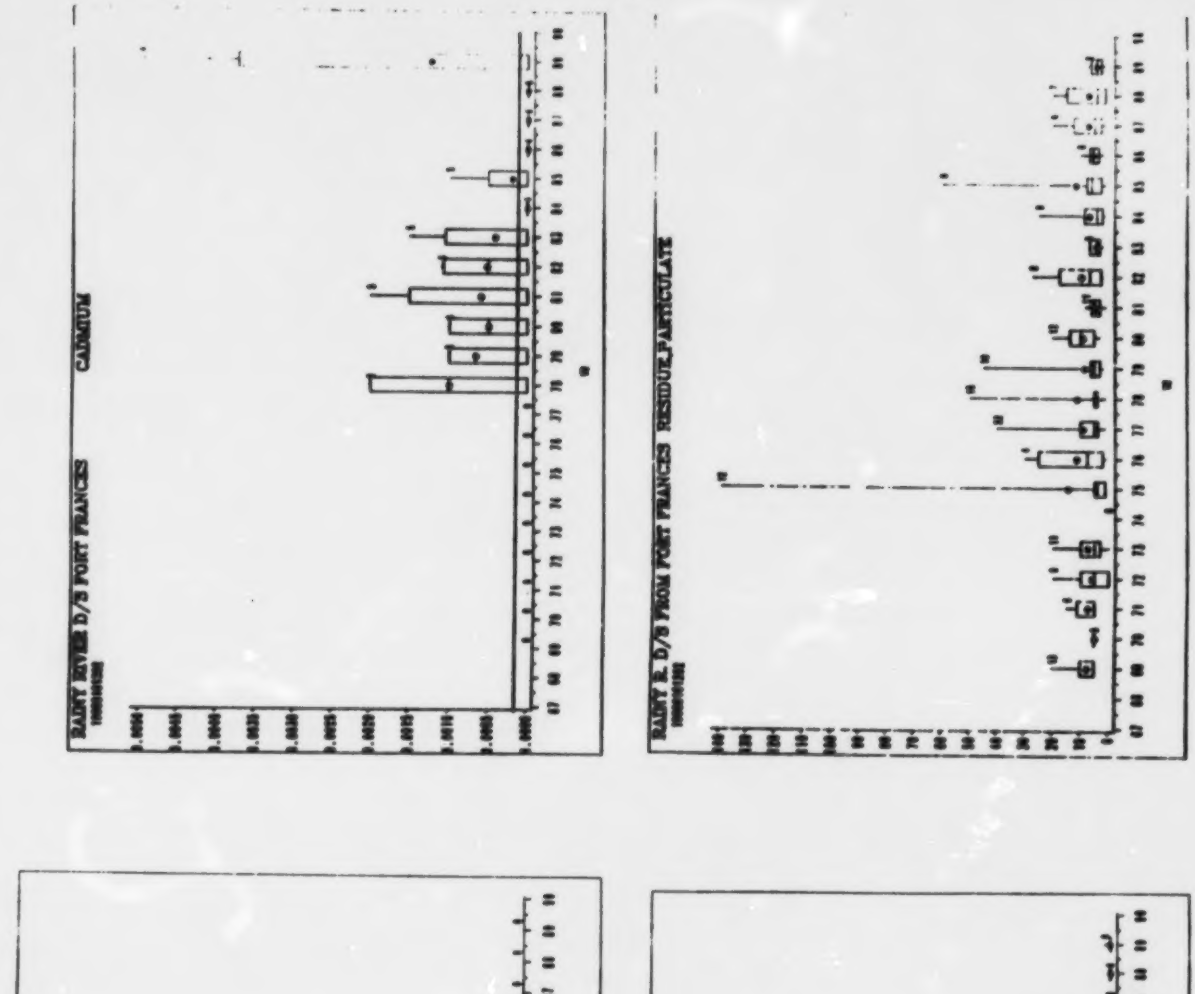


Fig. 131. Water quality in Rainy River D/S Fort Frances.

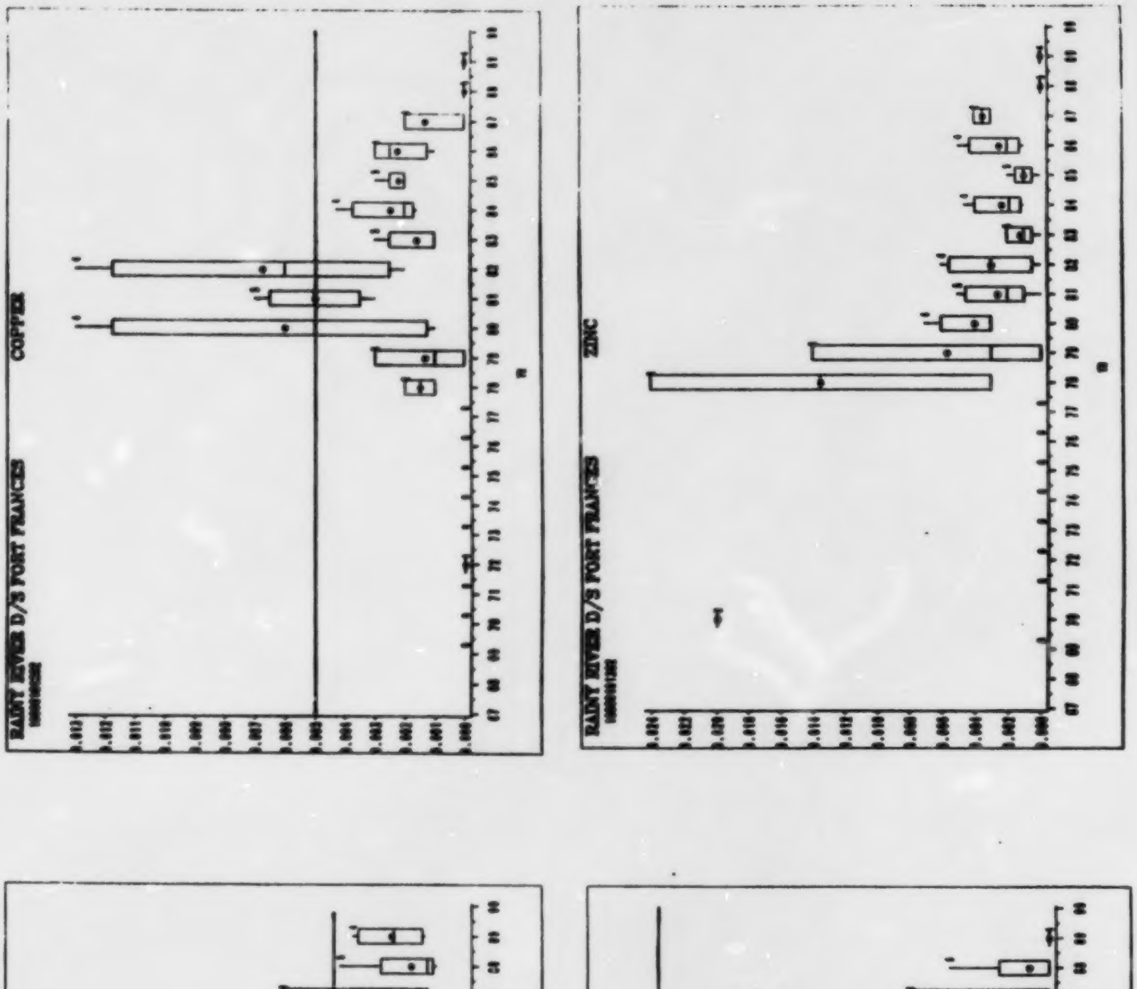


Fig. 132. Water quality in Rainy River D/S Fort Frances.

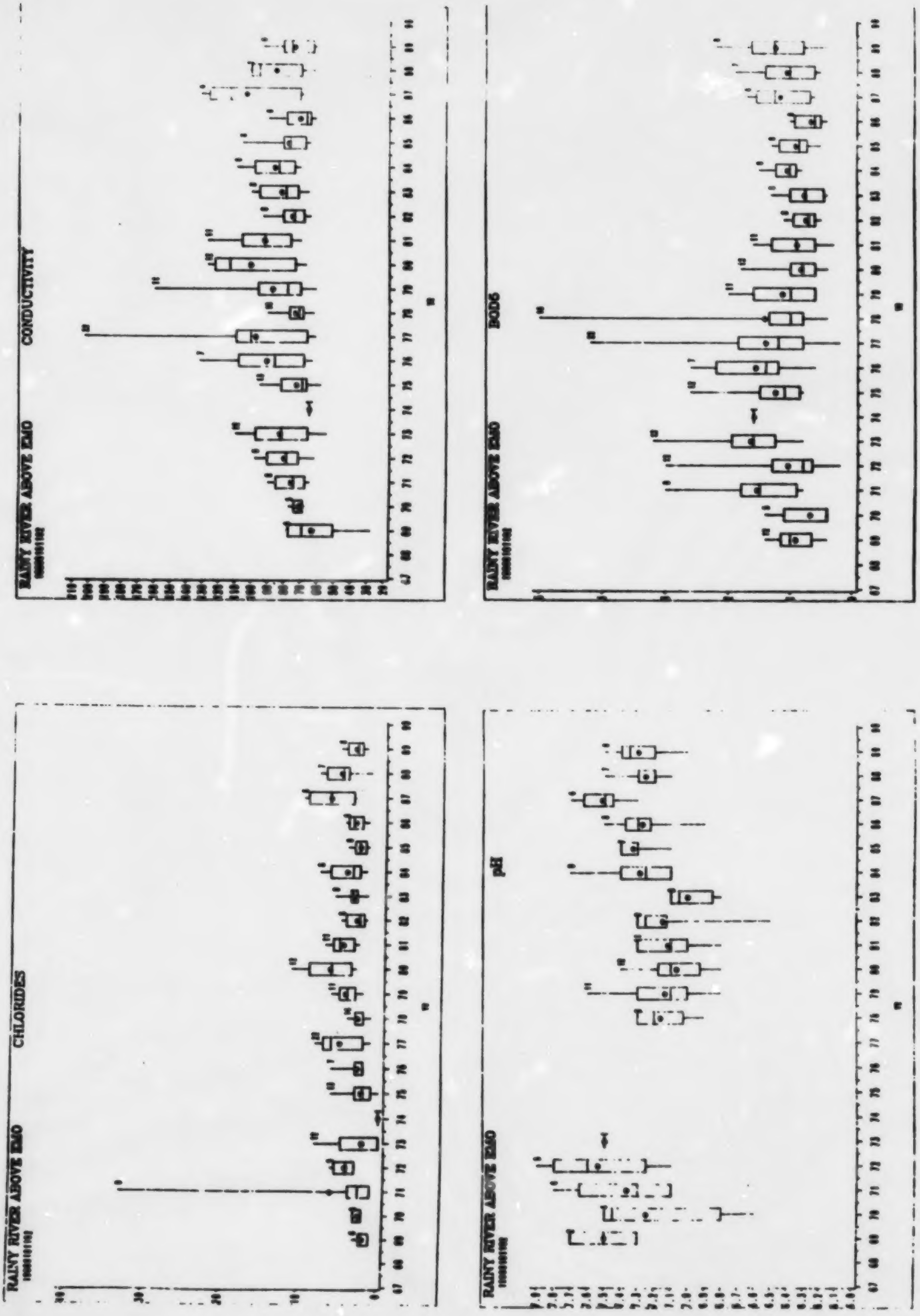


Fig. 133. Water quality in Rainy River U/S Emo.

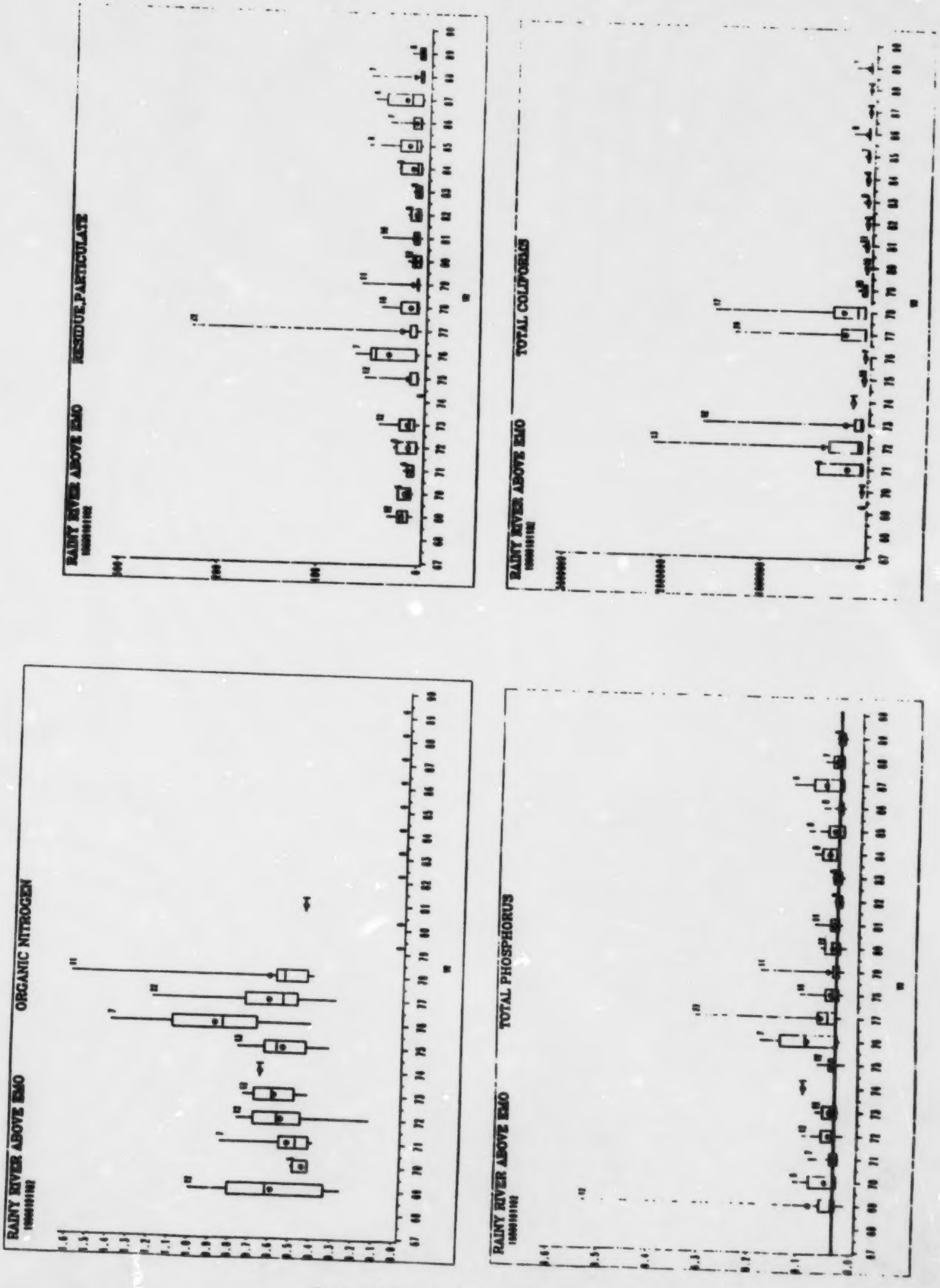
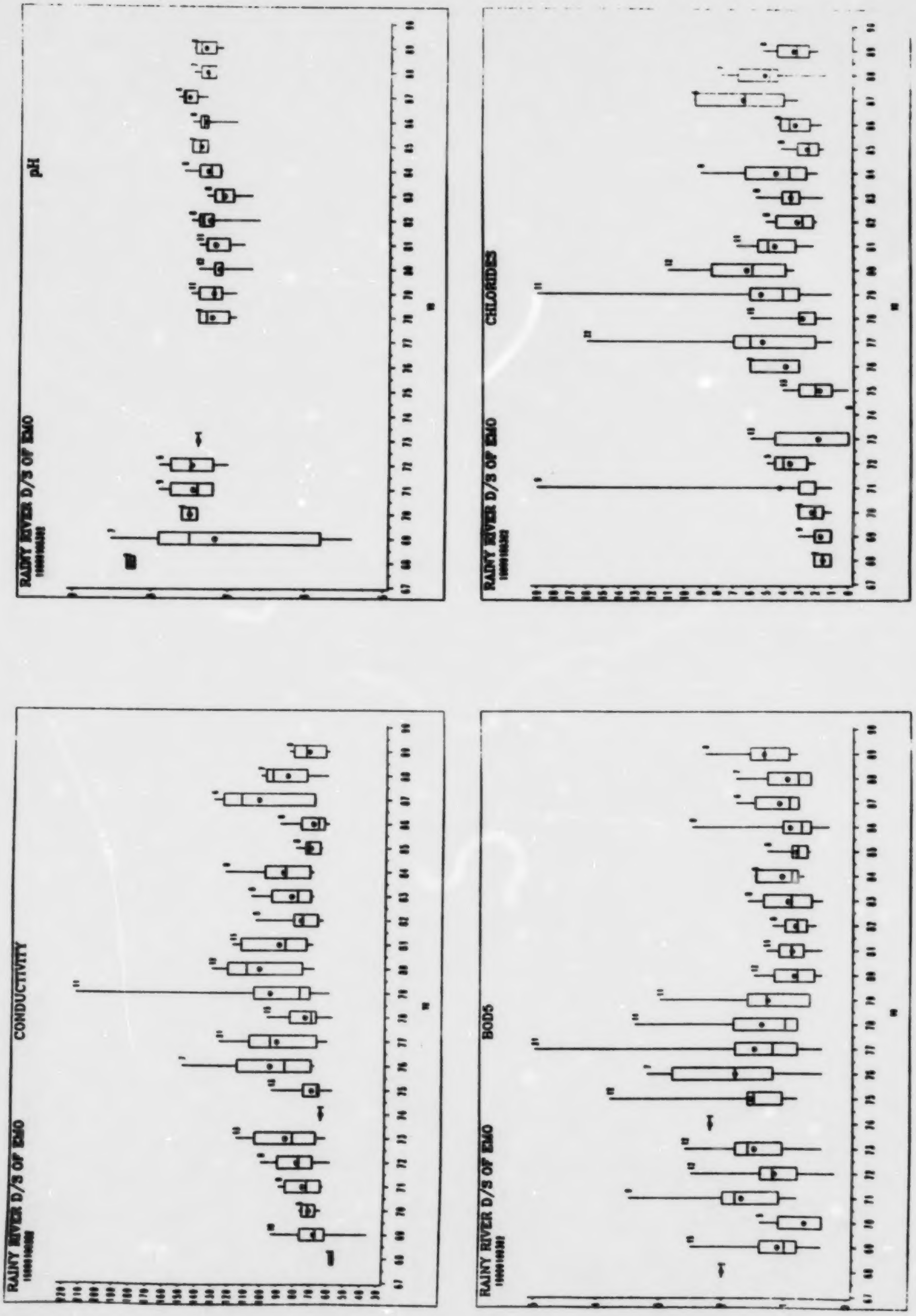


Fig. 134. Water quality in Rainy River U/S Emo.



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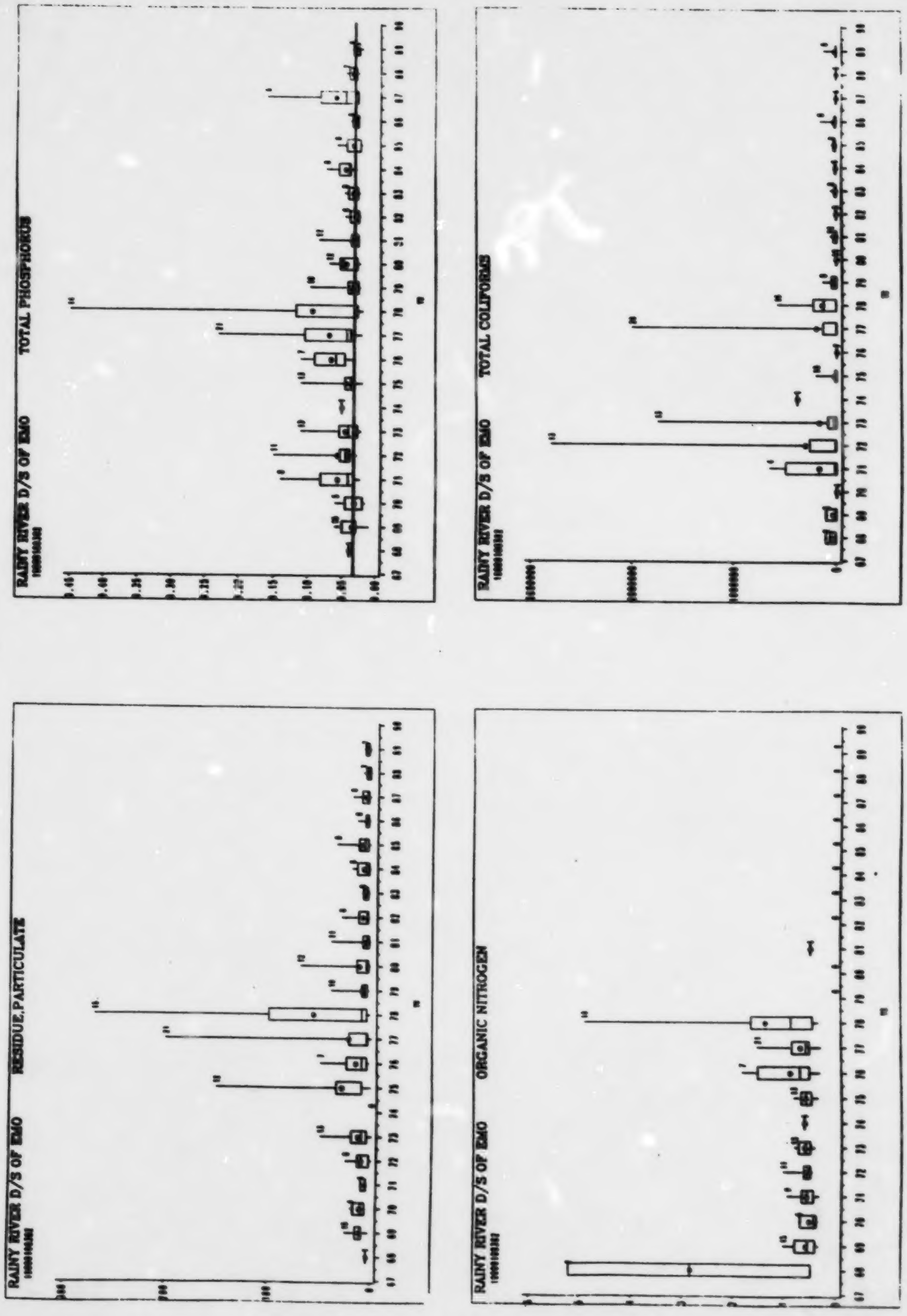

Fig. 136. Water quality in Rainy River D/S Emo.

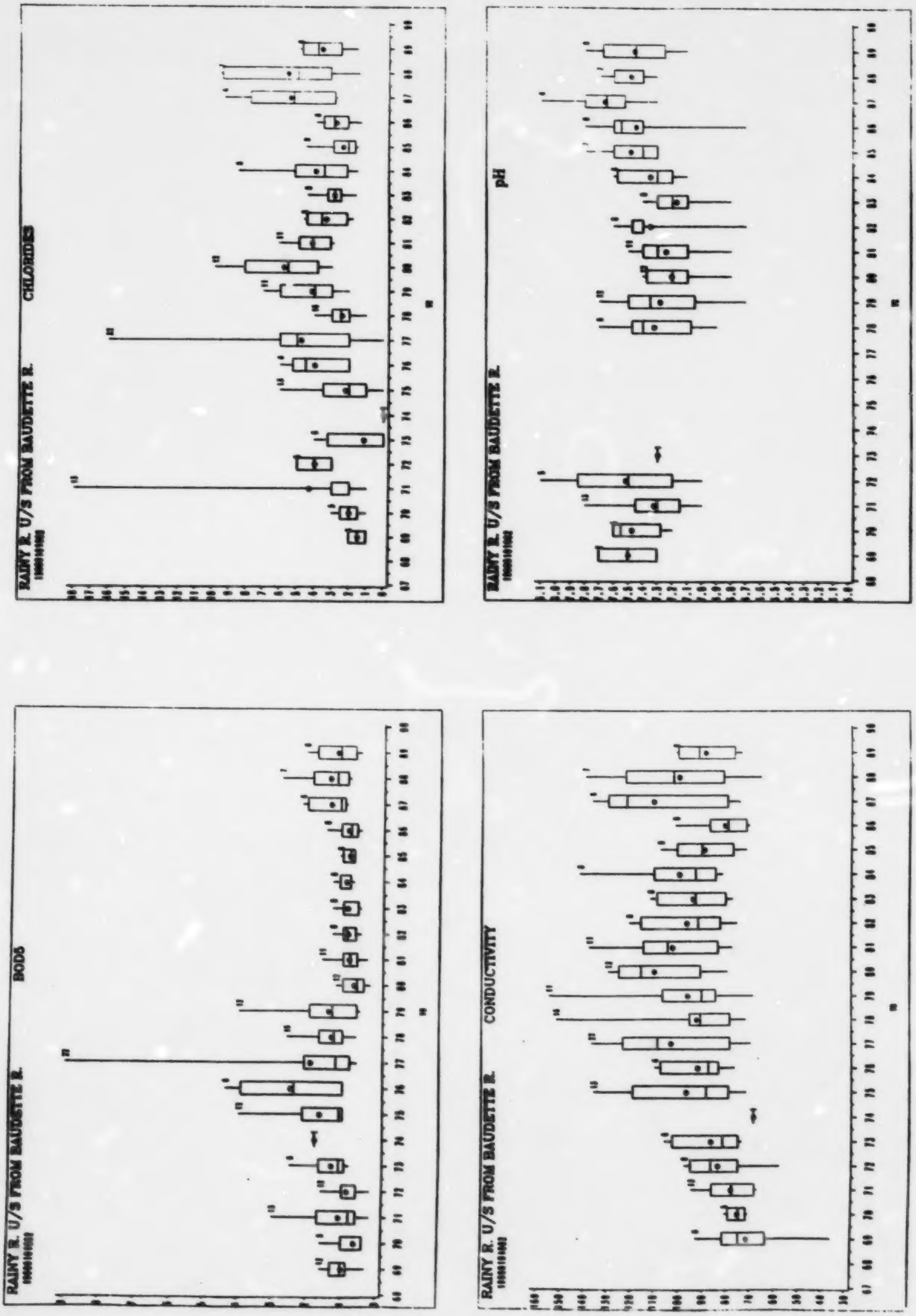

Fig. 137. Water quality in Rainy River U/S Baudette.

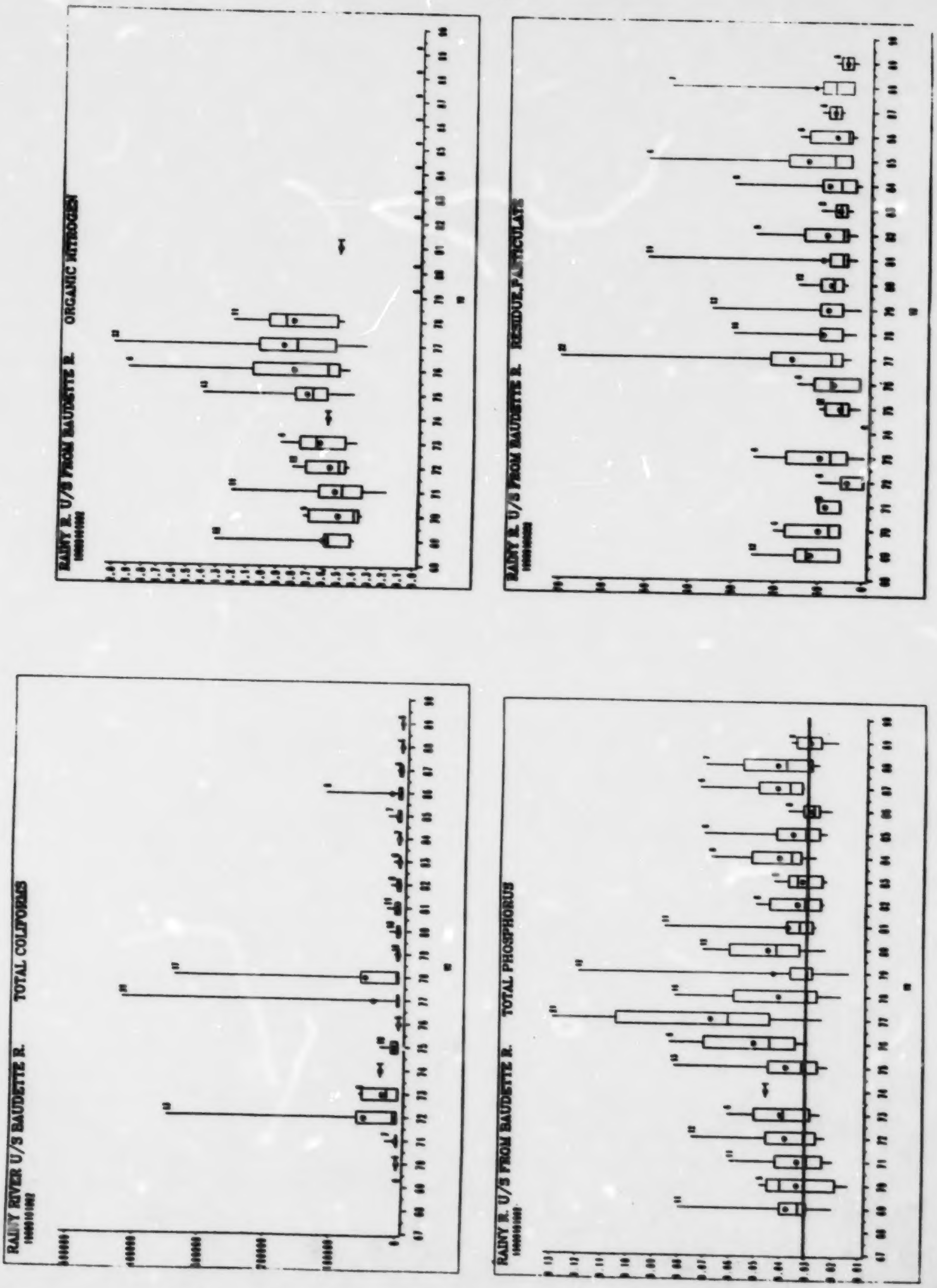

Fig. 138. Water quality in Rainy River U/S Baudette.

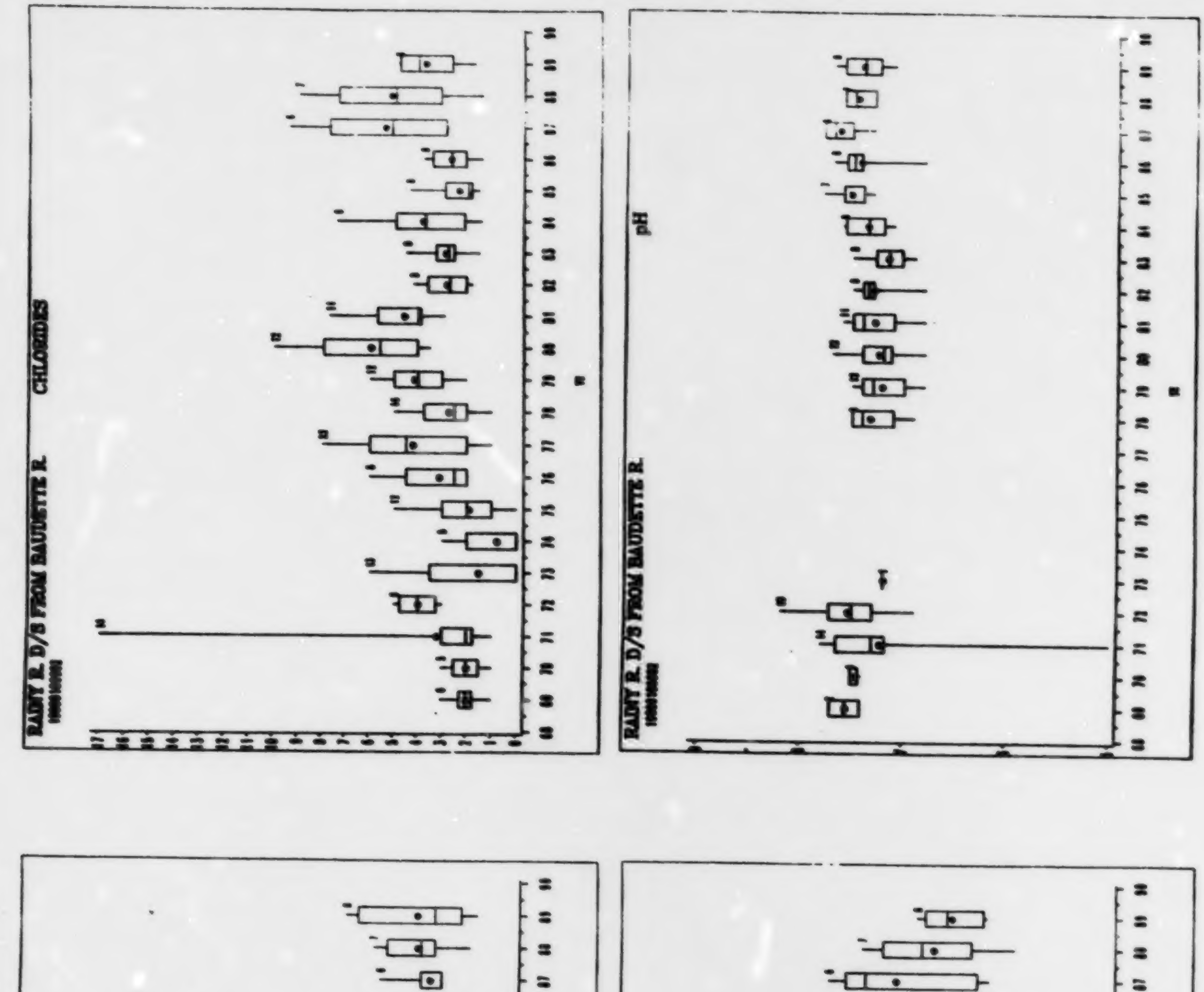

Fig. 139. Water quality in Rainy River D/S Baudette.

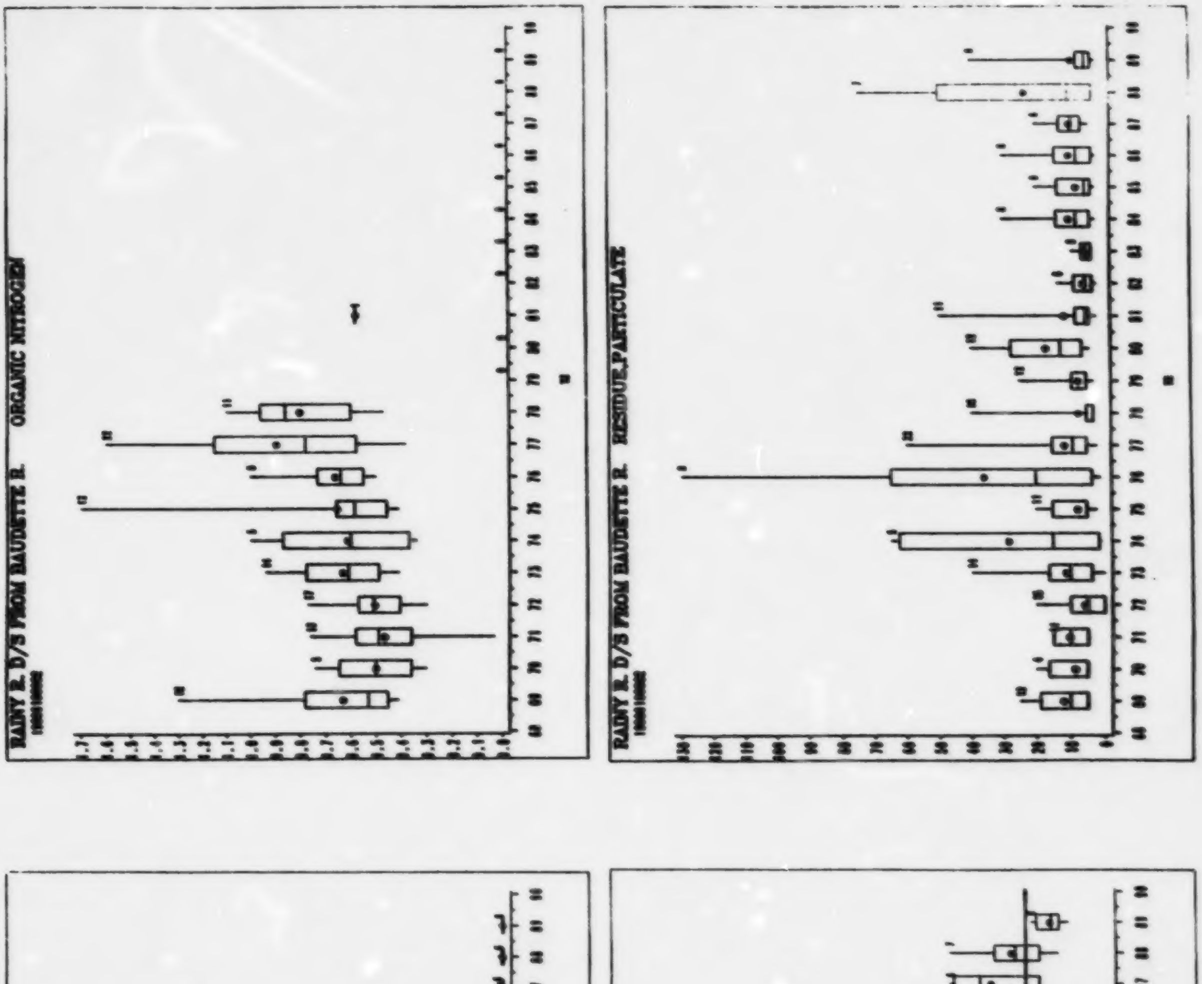

Fig. 140. Water quality in Rainy River D/S Baudette.

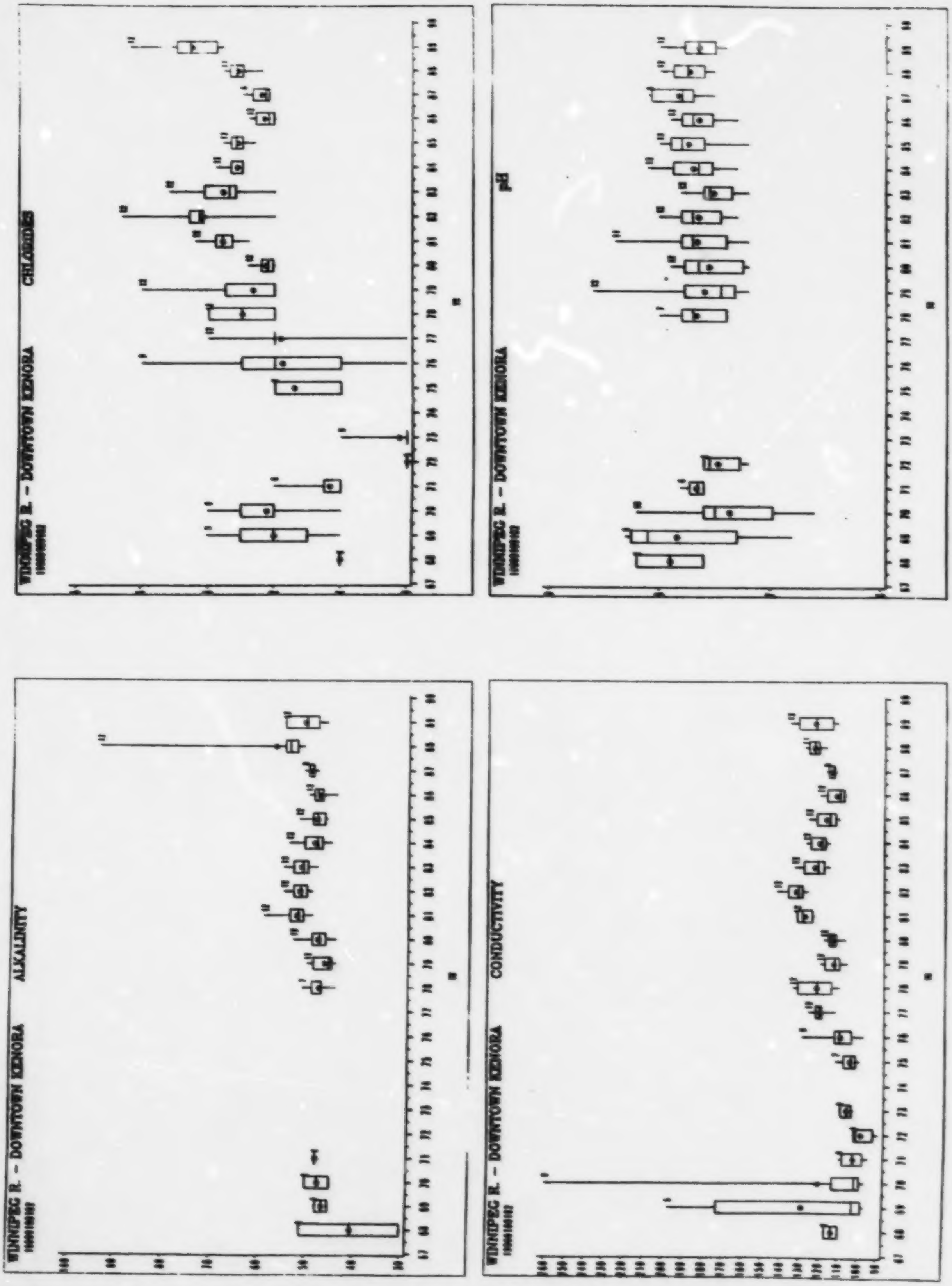

Fig. 141. Water quality in Winnipeg River downtown Kenora.

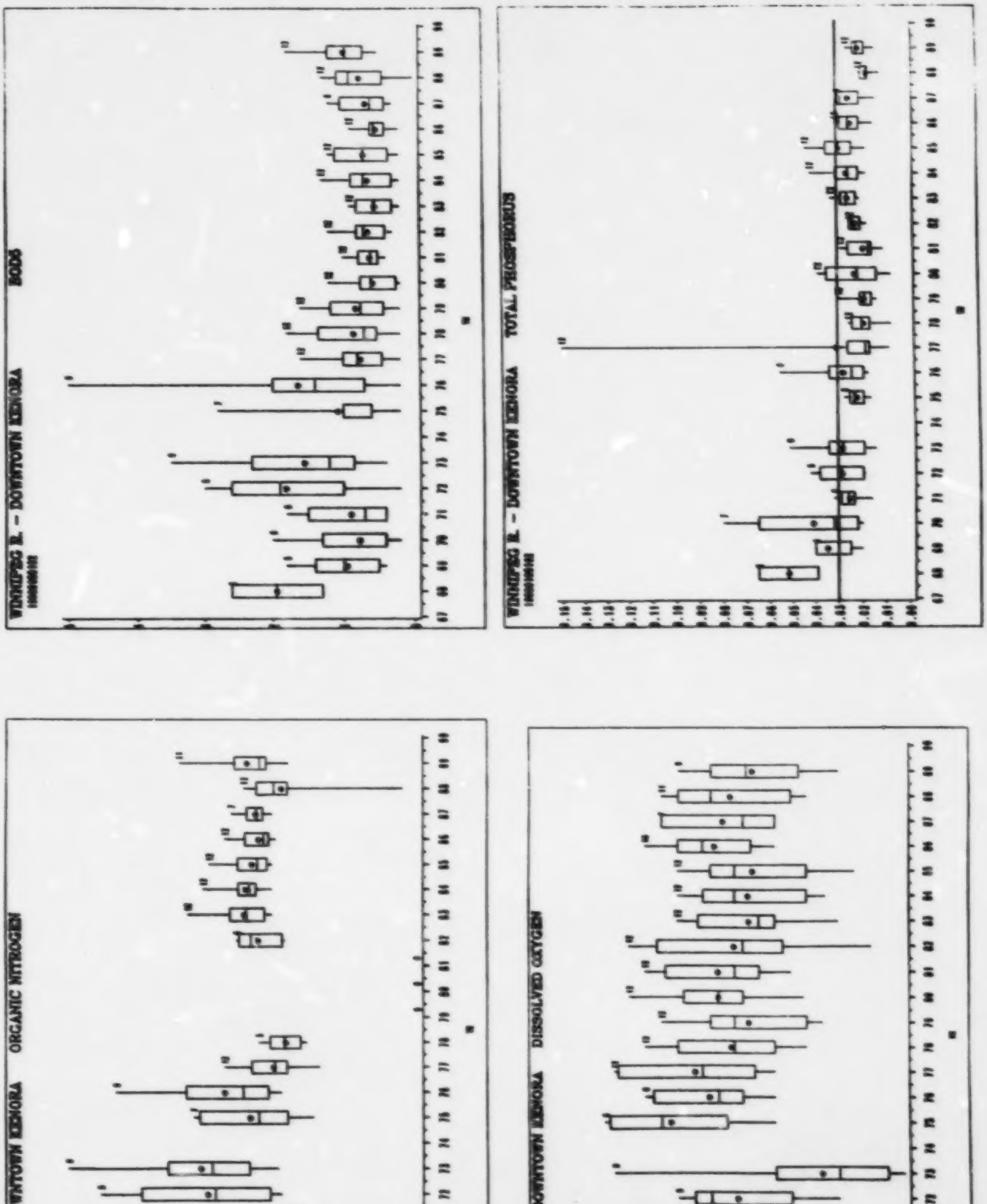

Fig. 142. Water quality in Winnipeg River downtown Kenora.

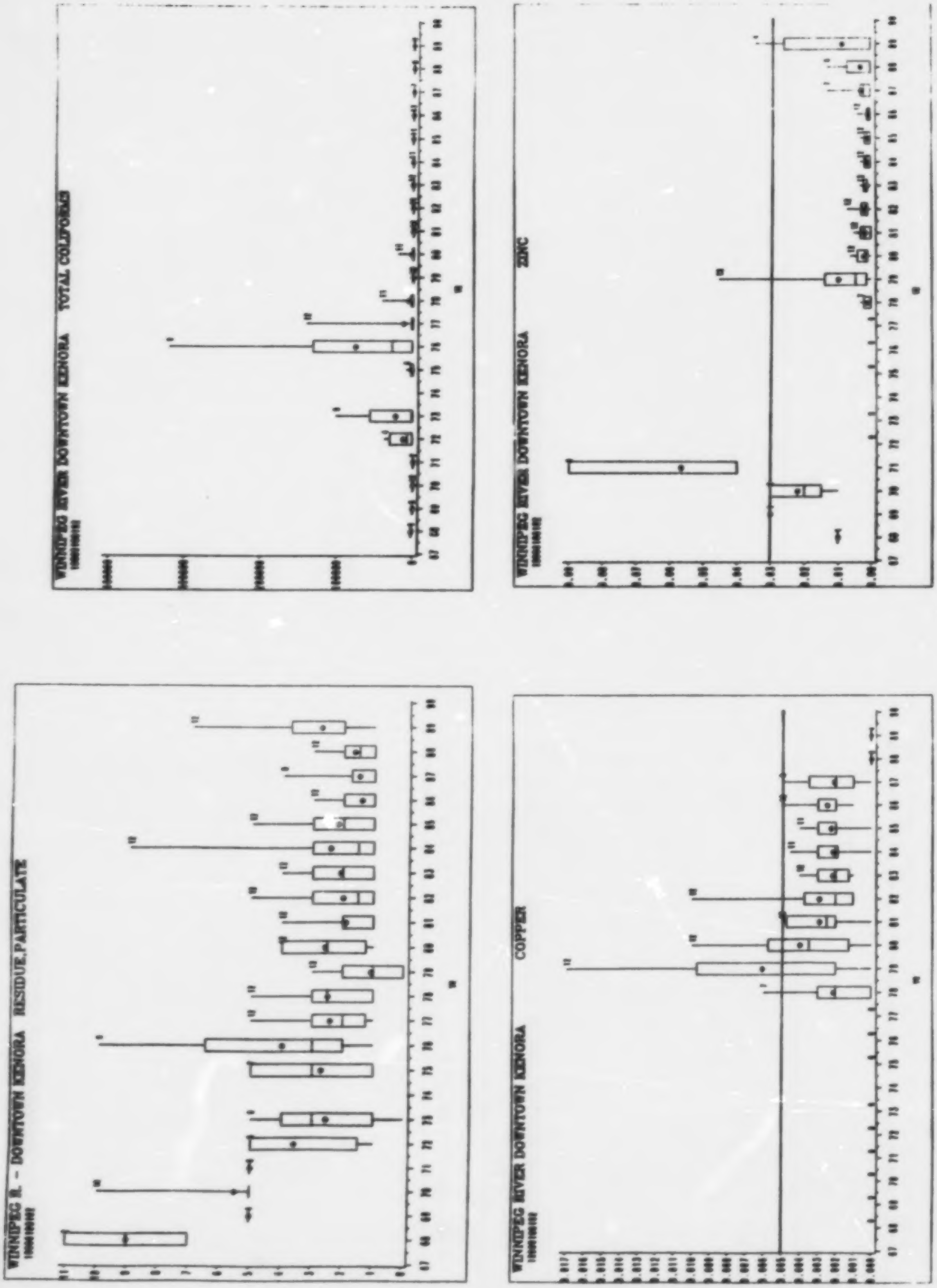

Fig. 143. Water quality in Winnipeg River downtown Kenora.

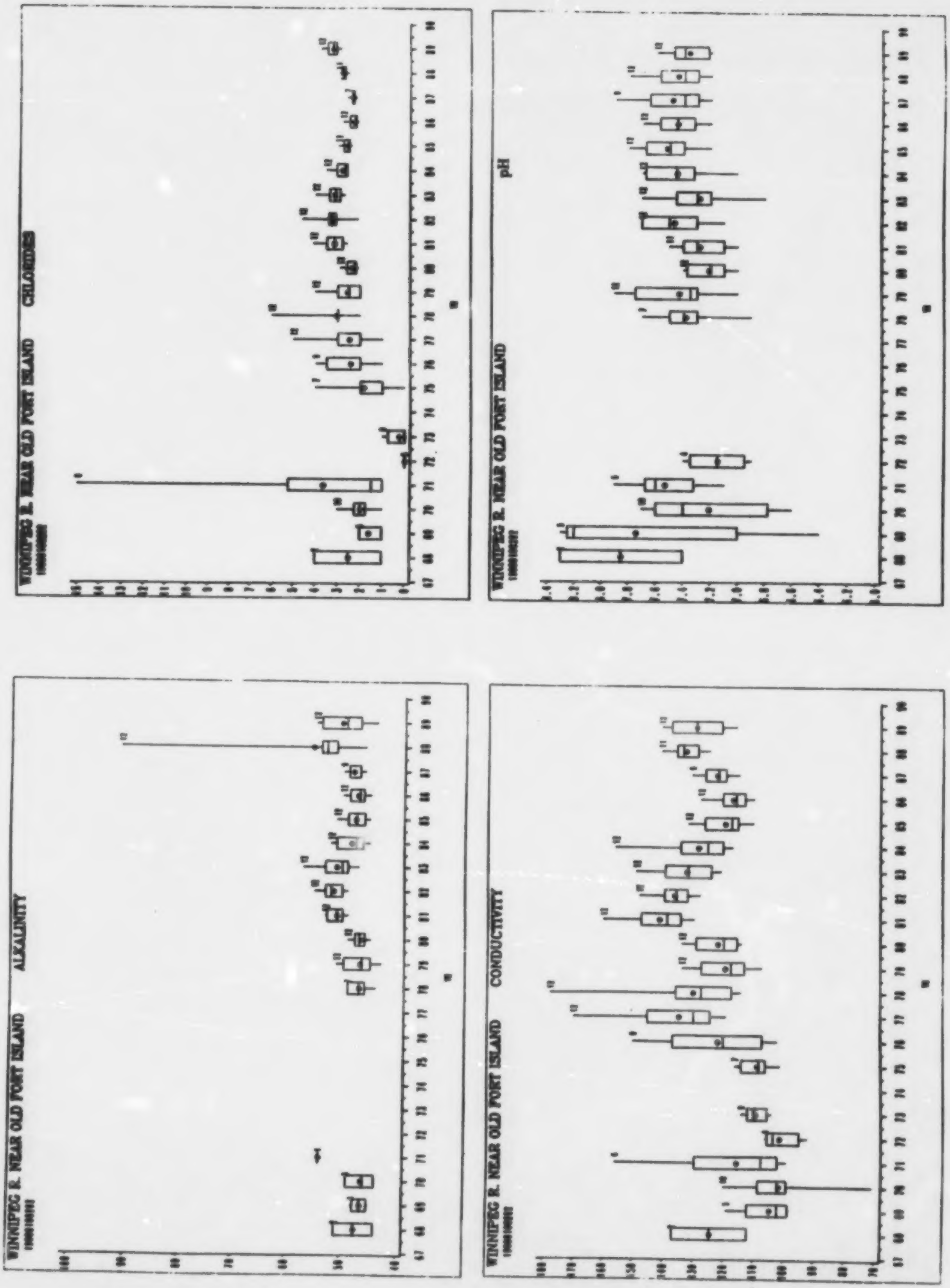

Fig. 144. Water quality in Winnipeg River D/S Old Fort Is.

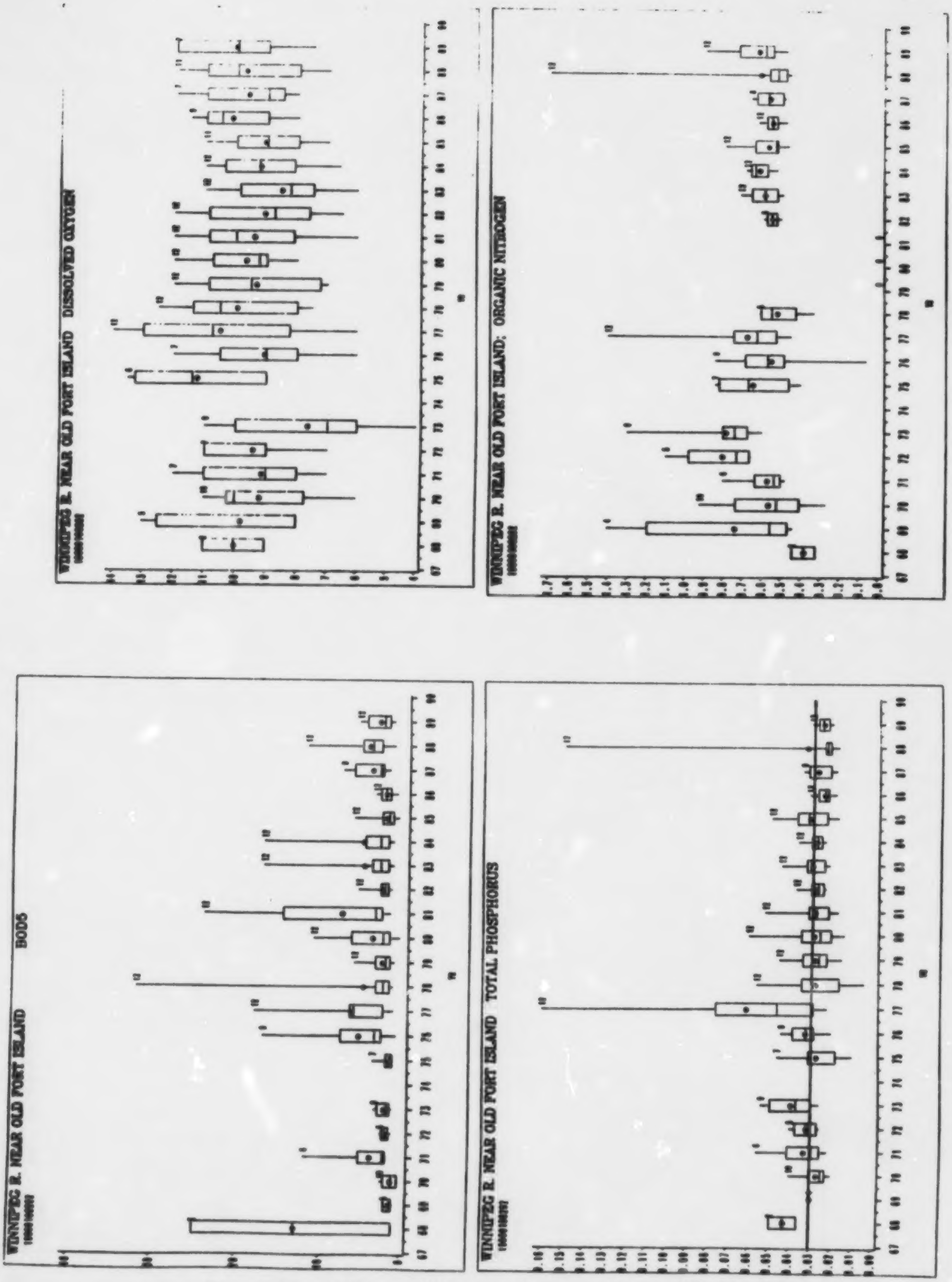

Fig. 145. Water quality in Winnipeg River D/S Old Fort Is.

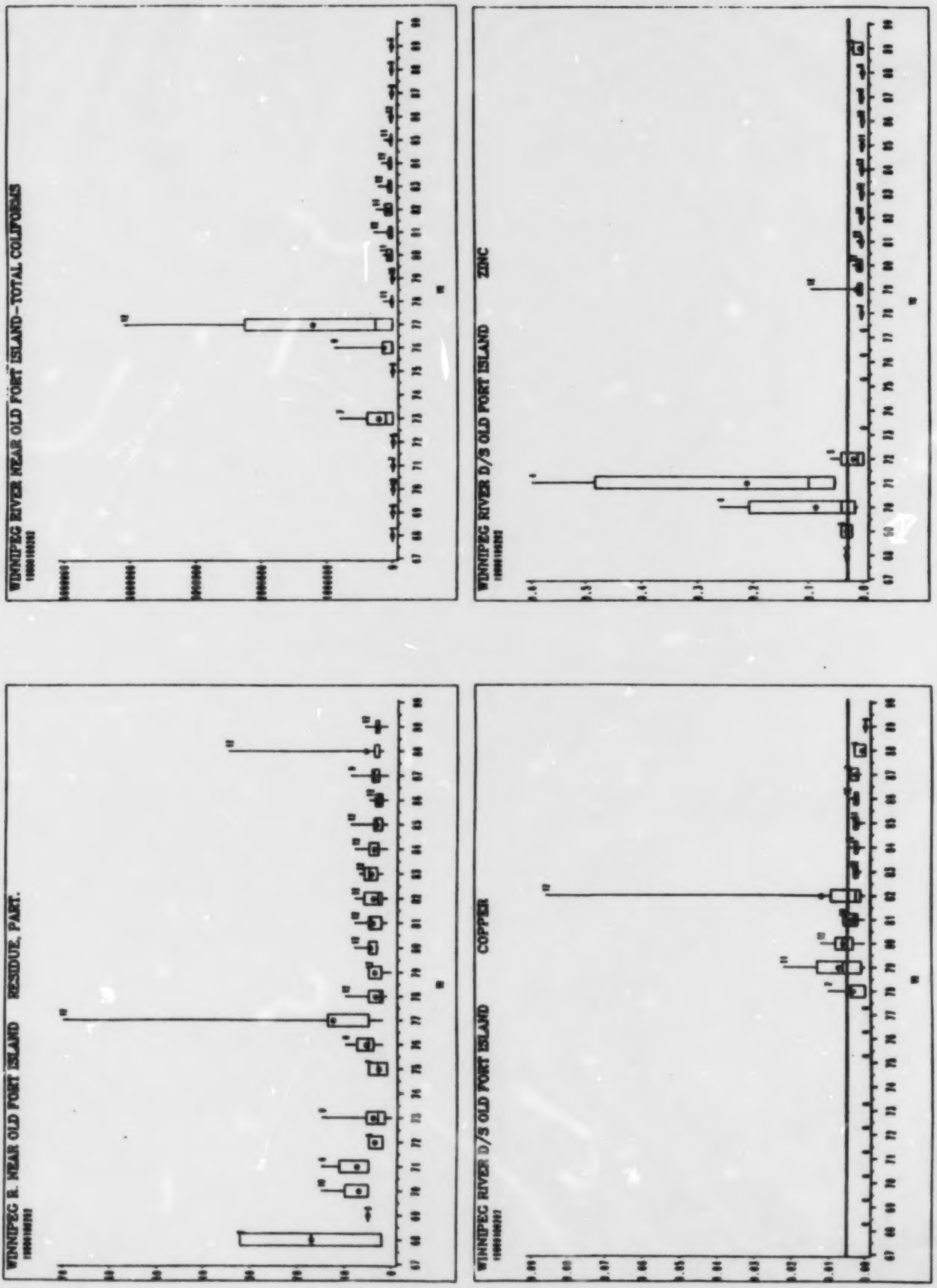

Fig. 146. Water quality in Winnipeg River D/S Old Fort Is.

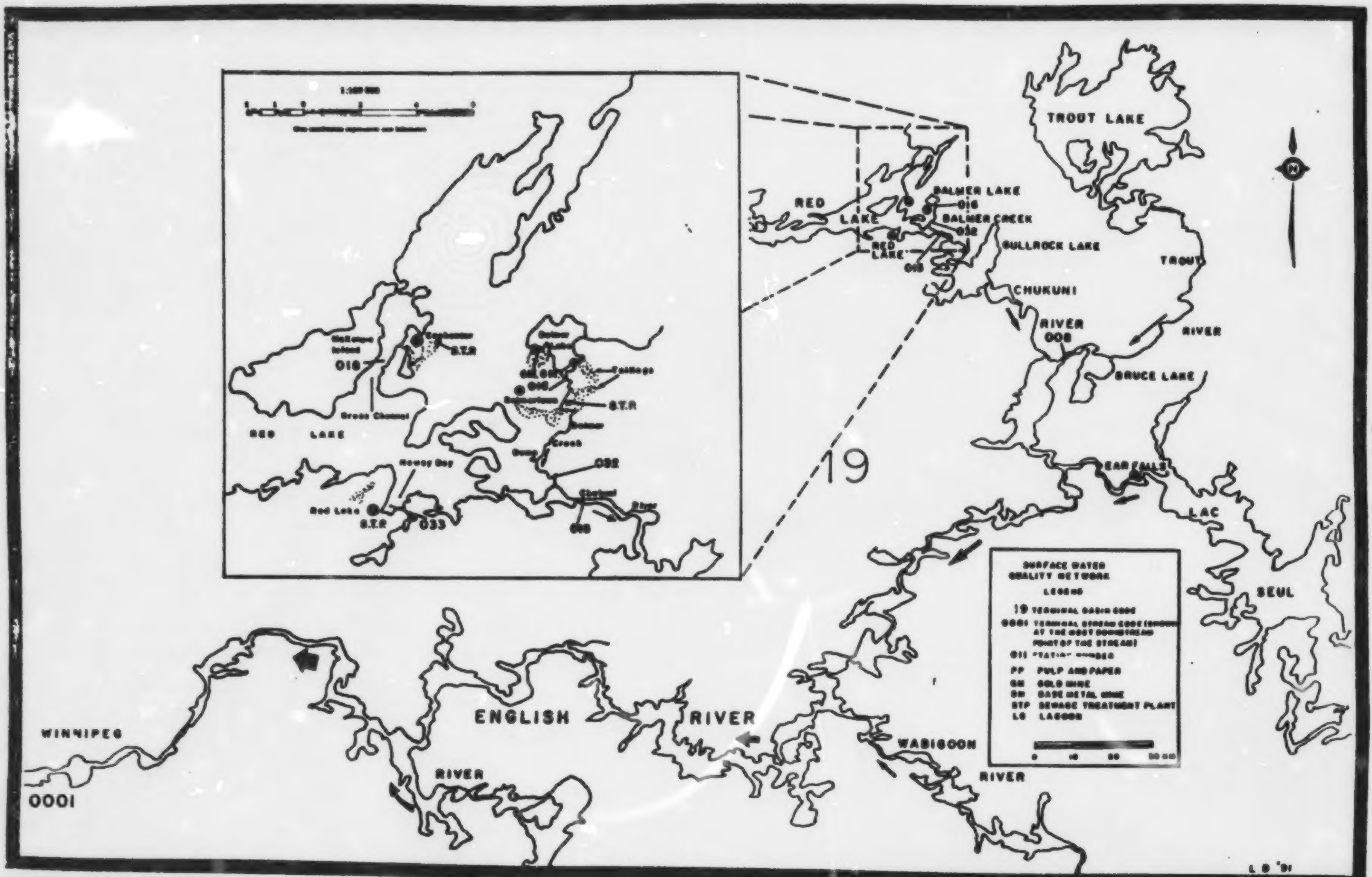
TROUT LAKE
RED
LAKE
RED LAKE
BALMER LAKE
016
BALMER CREEK
032
008
BULLROCK LAKE
TROUT
RIVER
CHUKUNI
RIVER
008
BRUCE LAKE
EAR FALLS
LAC
SEUL
19
ENGLISH
RIVER
WABIGOON
RIVER
RIVER
WINNIPEG
0001
SURFACE WATER
QUALITY NETWORK
LEGEND
19 TERMINAL BASIN CODE
0001 TERMINAL STREAM CODE (SHOWN AT THE MOST DOWNSTREAM POINT OF THE STREAM)
011 STATION NUMBER
PP PULP AND PAPER
GM GOLD MINE
BM BASE METAL MINE
STP SEWAGE TREATMENT PLANT
LG LAGOON
0
10
20
30 km
1:100 000
018
S.T.R
Green Channel
RED
LAKE
Howey Bay
Red Lake
S.T.R
033
Tailings
S.T.R
Balmer
Creek
032
008
River
L.B. '91

FIGURE147: WATER QUALITY MONITORING LOCATIONS AND POINT SOURCES FOR BALMER CREEK AND CHUKUNI RIVER IN THE RED LAKE AREA.

Table 9 Selected water quality parameters for the Red Lake area (long term median values unless specified).

Station	BOD mg/ℓ	Conductivity mg/ℓ	Chlorides mg/ℓ	Suspended Solids mg/ℓ	Total Phosphorus mg/ℓ	Nitrogen mg/ℓ	Sulphates mg/ℓ	Total Coliform /100 ml	Fecal Coliform /100 ml
Troutlake R. -0001-008-	0.8	90	1.0	5	0.027	NH_4:0.03 NTK:0.46	3.7	16	0
Balmer O/F Lake -0001-016-	1.8 6.7*	505 1470*	40.5 108*	10 35*	0.120 0.74*	NH_4:1.30 NTK:2.70	74.0 197*	66	0
Lower Balmer Creek -0001-032-	2.0	447	37.0	8	0.140	NH_4:0.39	68.0	1100	10
Chukuni River -0001-015-	0.9	66	1.0	2	0.022	NH_4:0.02	4.6	29	0
Red Lake Bruce Channel (-0001-018-)	0.7	60	0.7	1	0.015	NTK:0.39	3.0	12	0
Red Lake Howey Bay (-0001-033-)	0.8	62	0.8	1	0.017	NTK:0.38	3.3	16	0

* maximum value for 1989
NH_4 ammonia/ium
NTK total Kjeldahl nitrogen

Table 10 Selected metals and cyanide (median values) in Red Lake area waters.

Station	Zinc mg/ℓ	Copper mg/ℓ	Nickel mg/ℓ	Arsenic mg/ℓ	Mercury µg/ℓ	Total Cyanide mg/ℓ
Trout Lake River (-0001-008-)	0.003	0.002	<	0.002	<	0.001
Upper Balmer Creek (-0001-032-)	0.150	0.420	0.575	0.610	0.070	0.170
Lower Balmer Creek (-0001-032-)	0.066	0.210	0.360	0.500	0.045	0.080
Chukuni River (-0001-015-)	0.003	0.005	0.005	0.017	<	0.0005
Red Lake Bruce Channel (-0001-018-)	0.002	0.002	<	0.008	<	<
Howey Bay (-001-003-)	0.001	0.002	<	0.007	<	<

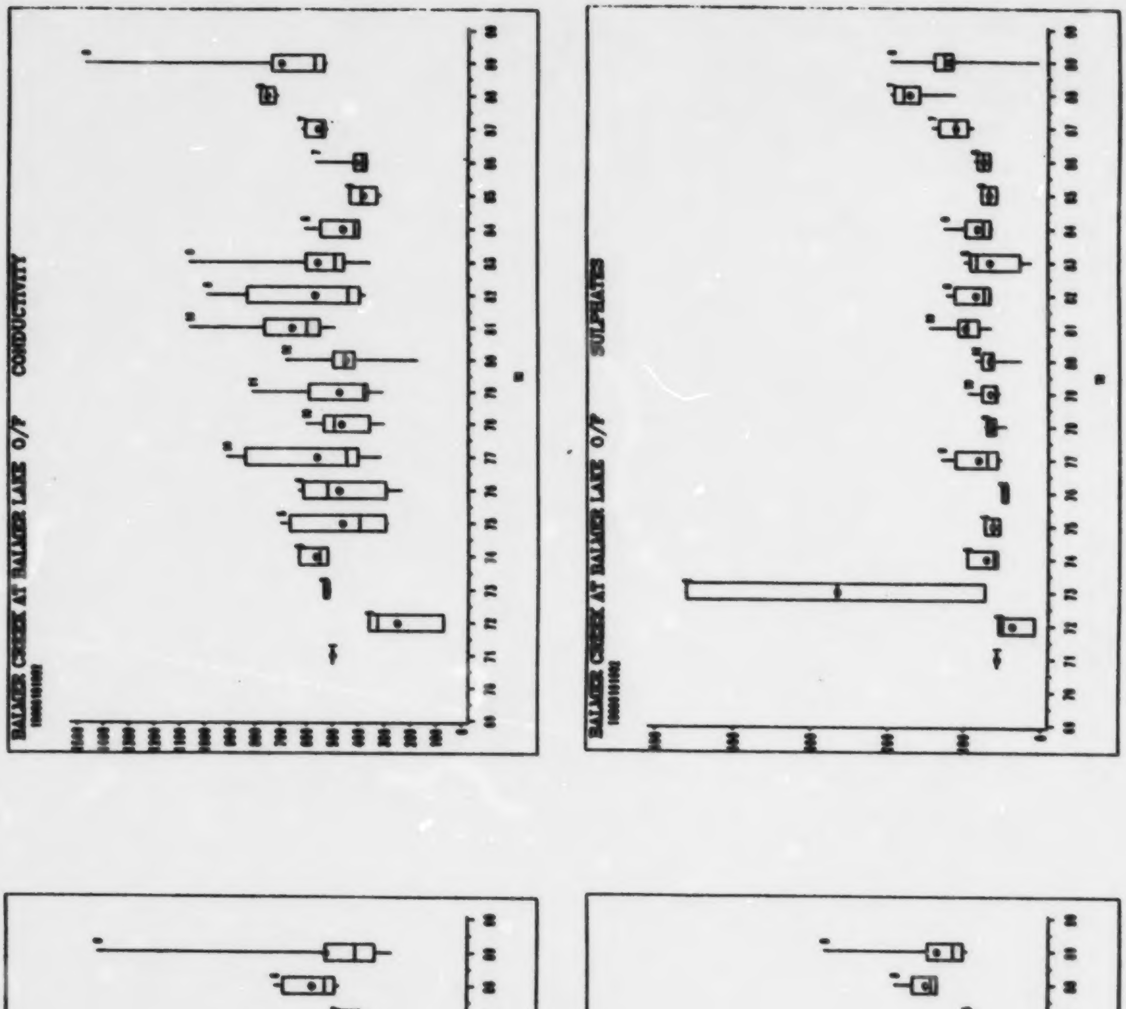

Fig. 148. Water quality in Upper Balmer Creek (O/F Balmer Lk.).

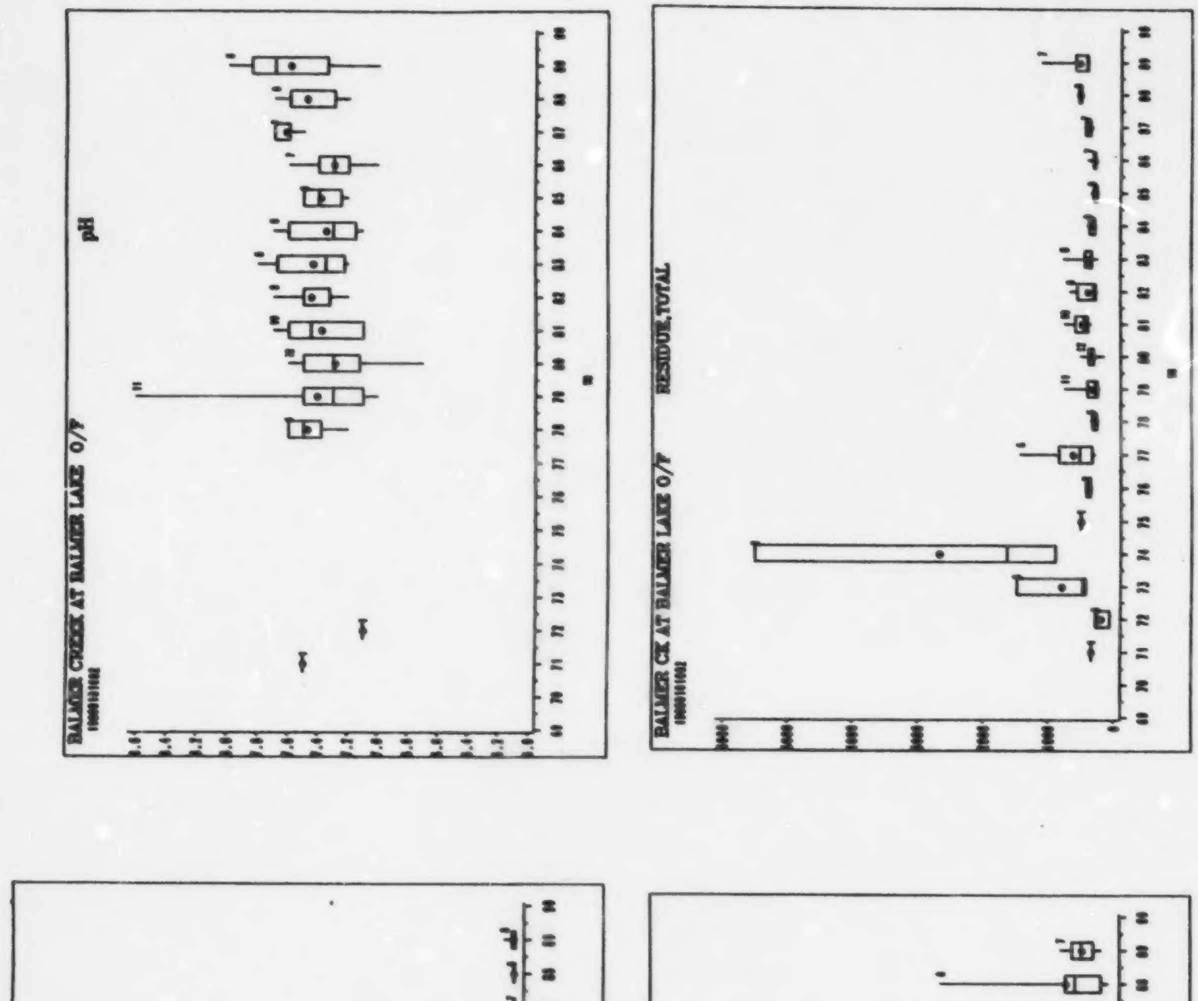

Fig. 149. Water quality in Upper Balmer Creek (O/F Balmer Lk.).

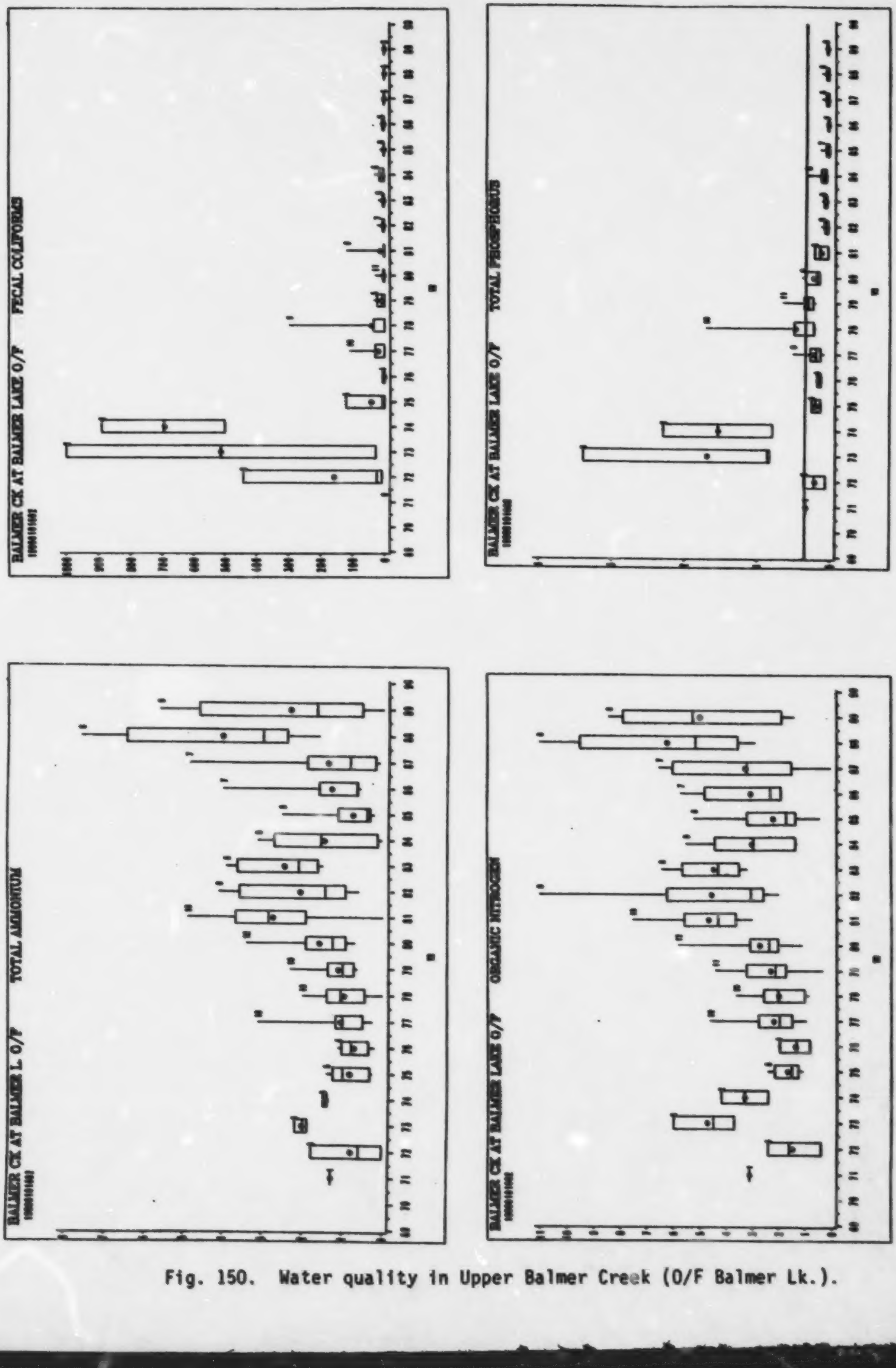

Fig. 150. Water quality in Upper Balmer Creek (O/F Balmer Lk.).

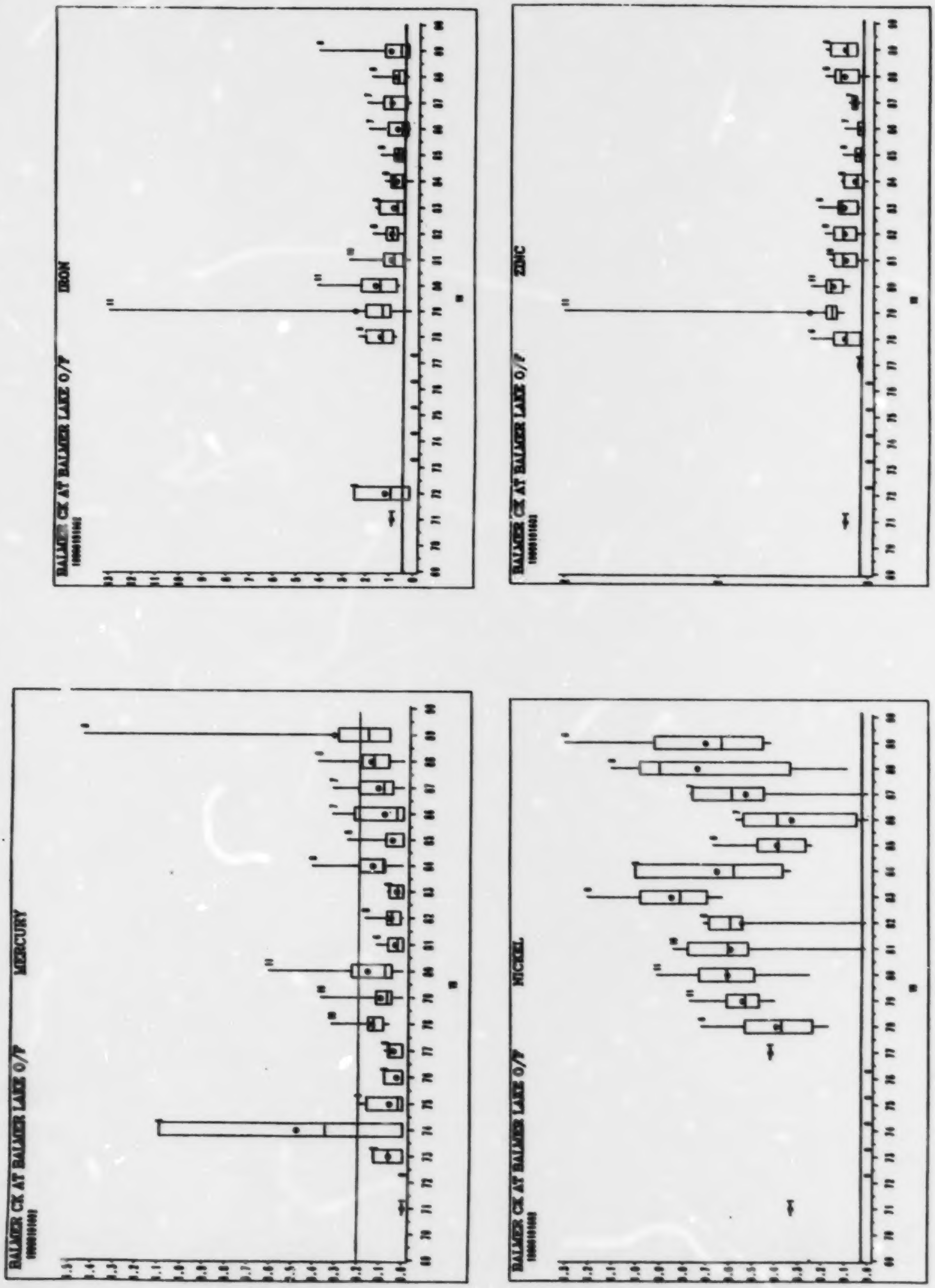

Fig. 151. Water quality in Upper Balmer Creek (O/F Balmer Lk.).

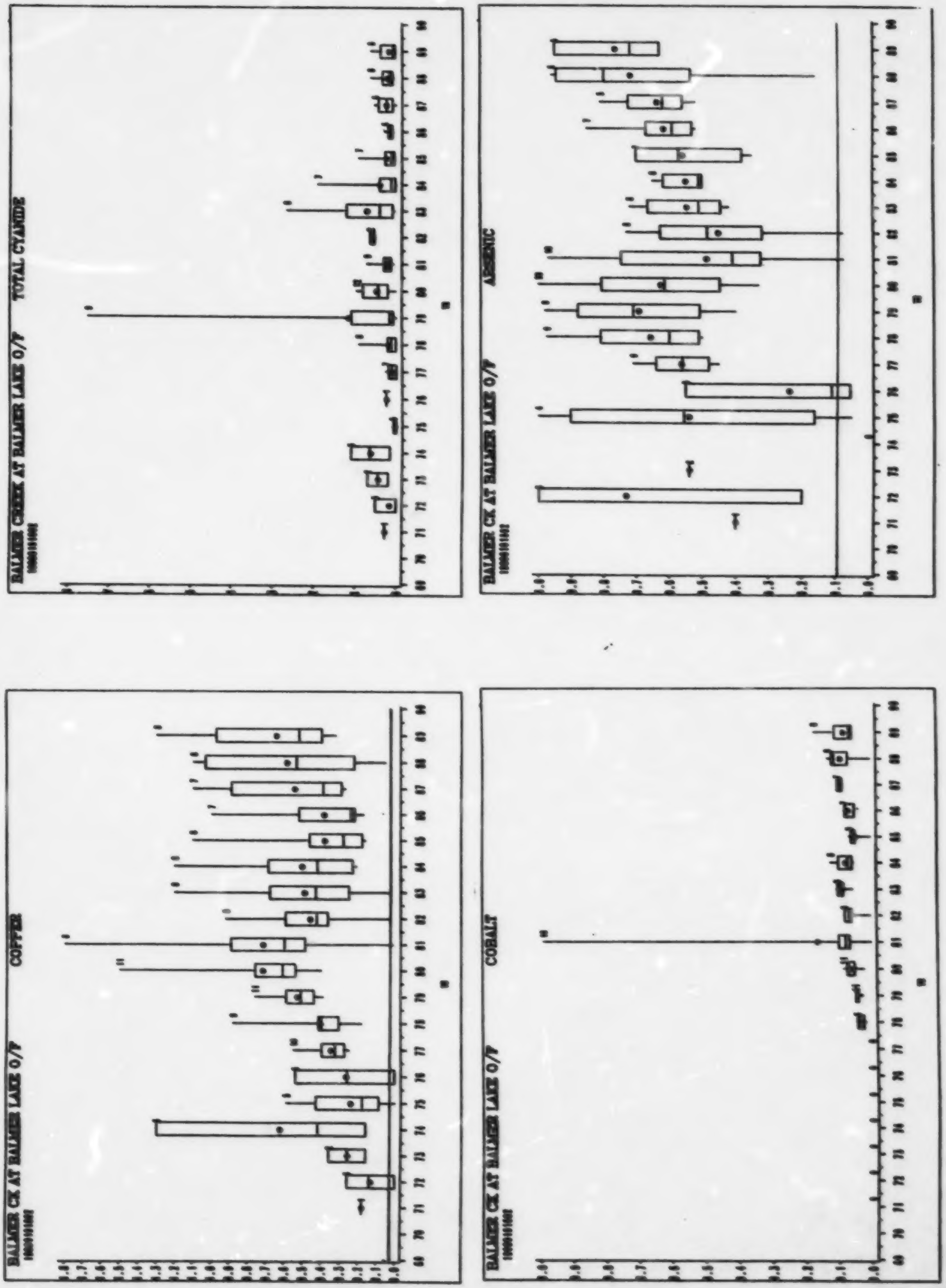

Fig. 152. Water quality in Upper Balmer Creek (O/F Balmer Lk.).

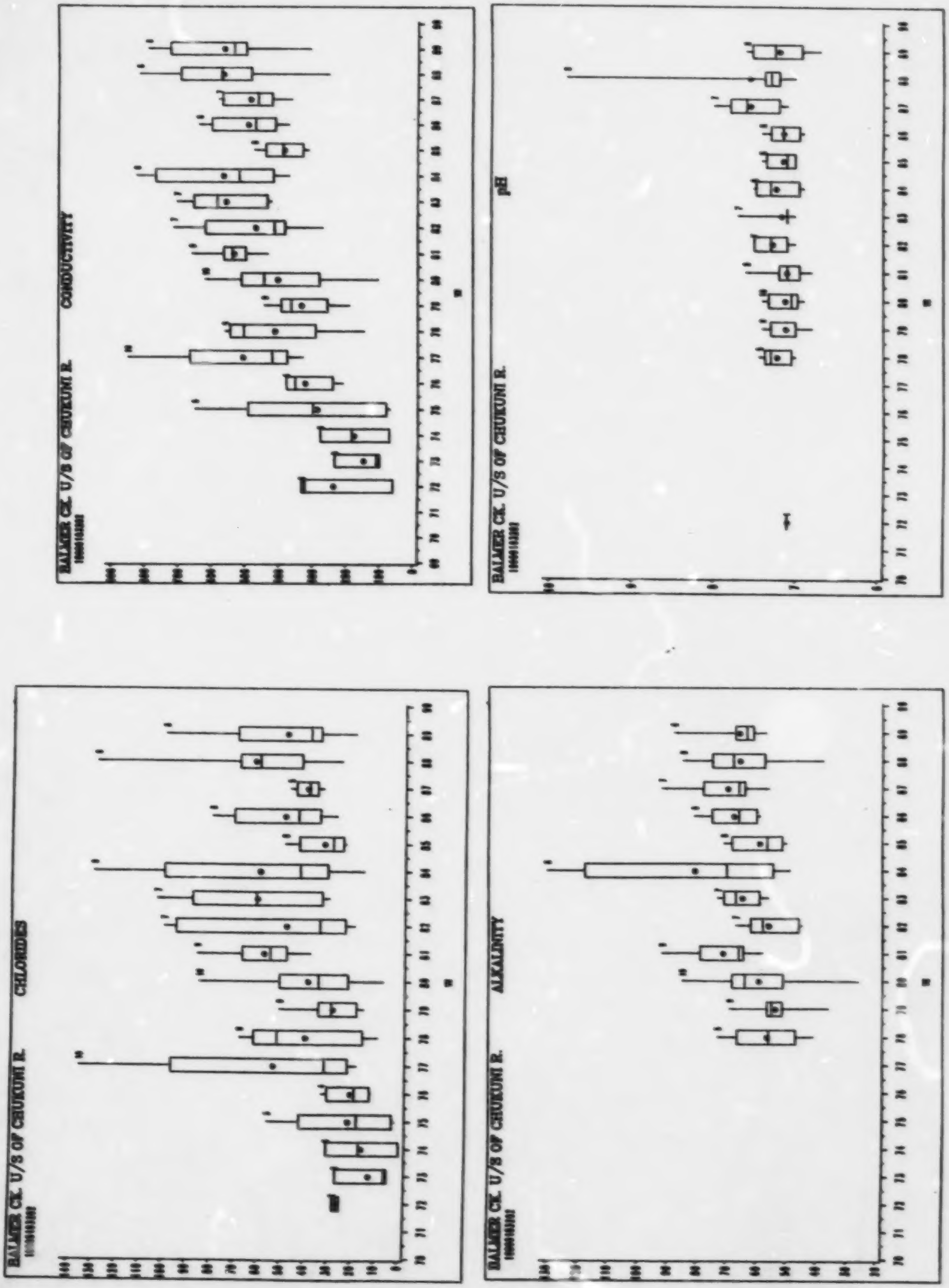

Fig. 153. Water quality in lower Balmer Creek (U/S Chukuni R.).

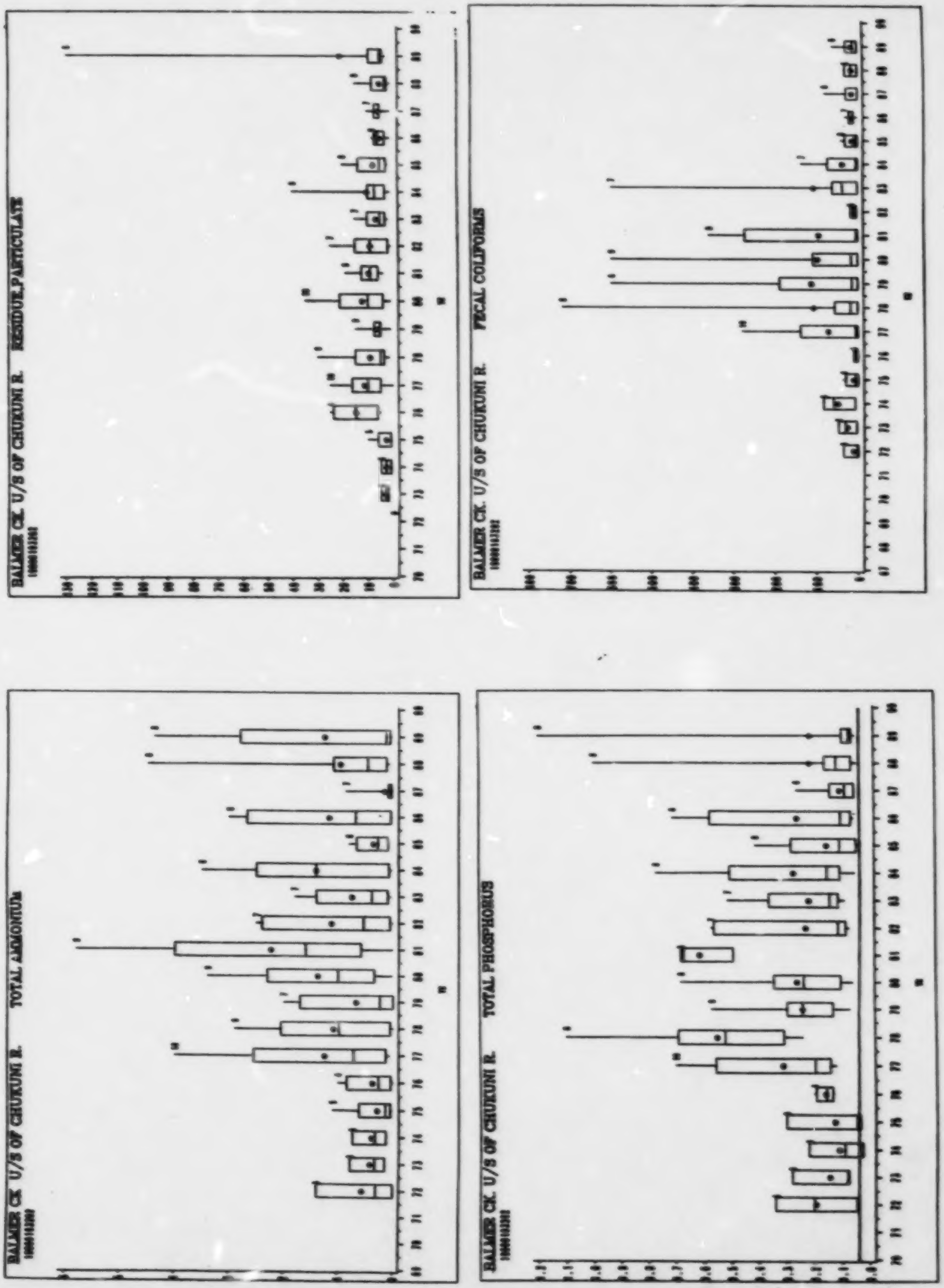

Fig. 154. Water quality in lower Balmer Creek (U/S Chukuni R.).

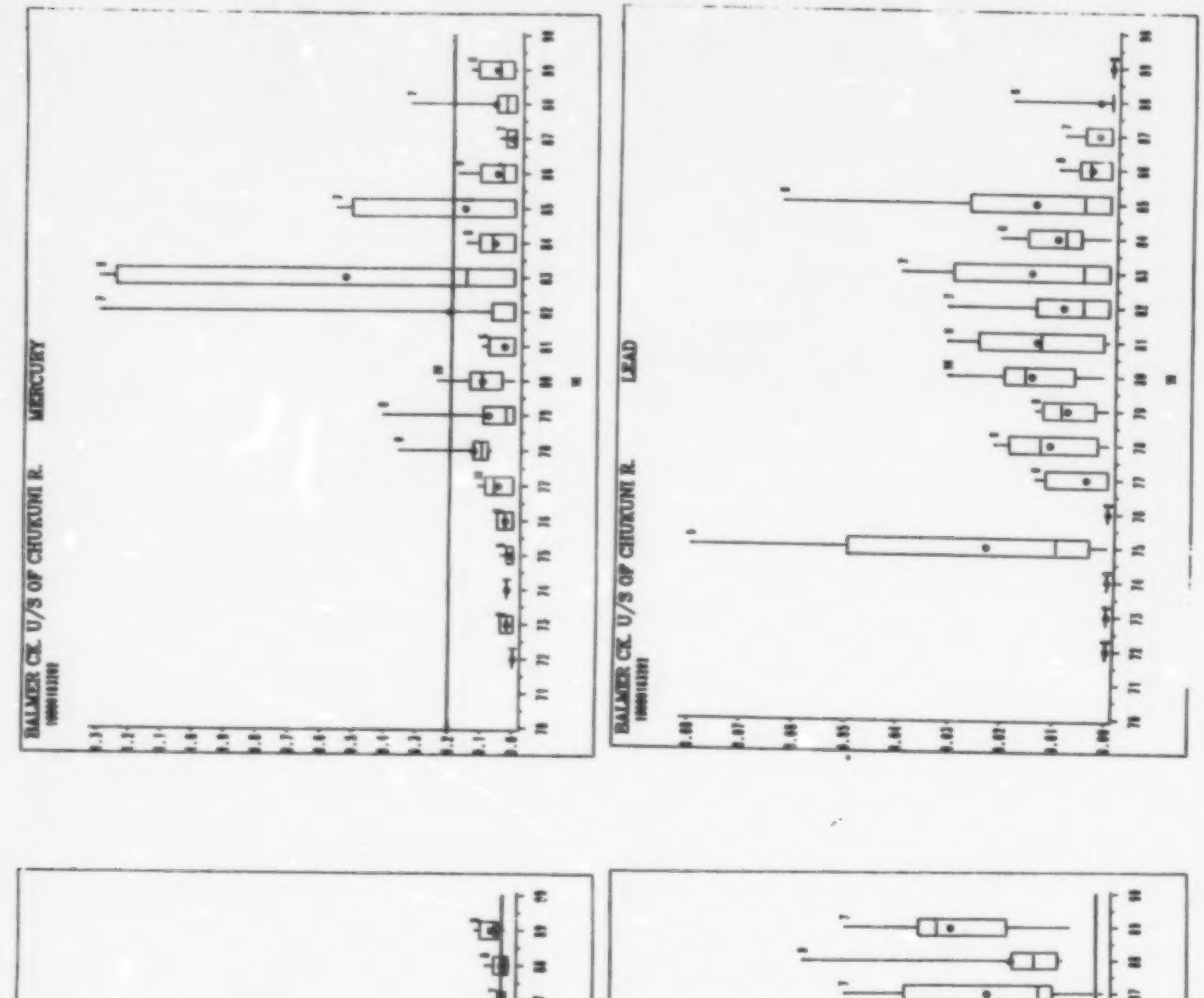

Fig. 155. Water quality in lower Balmer Creek (U/S Chukuni R.).

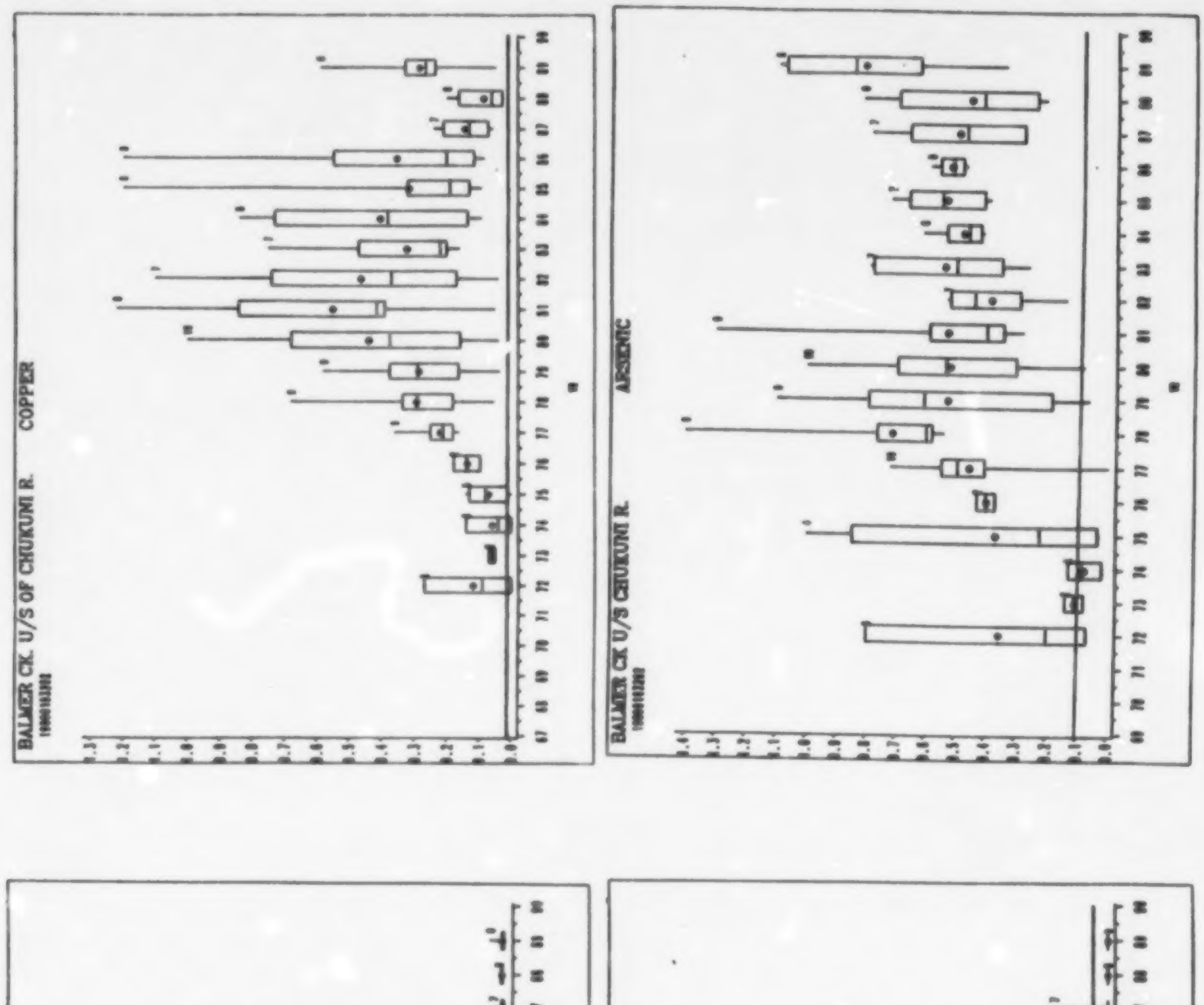

Fig. 156. Water quality in lower Balmer Creek (U/S Chukuni R.).

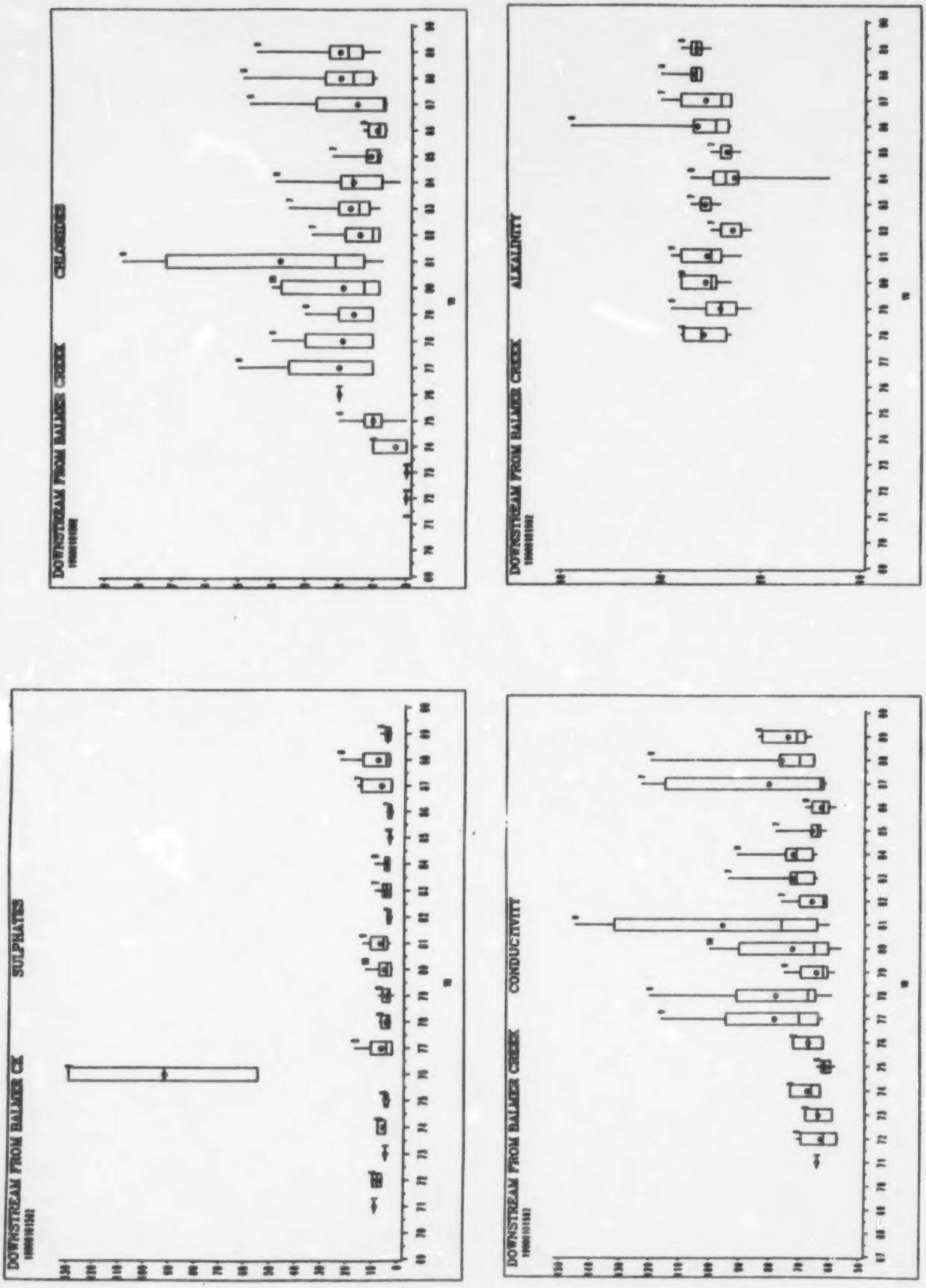

Fig. 157. Water quality in Chukuni R. D/S from Balmer Creek.

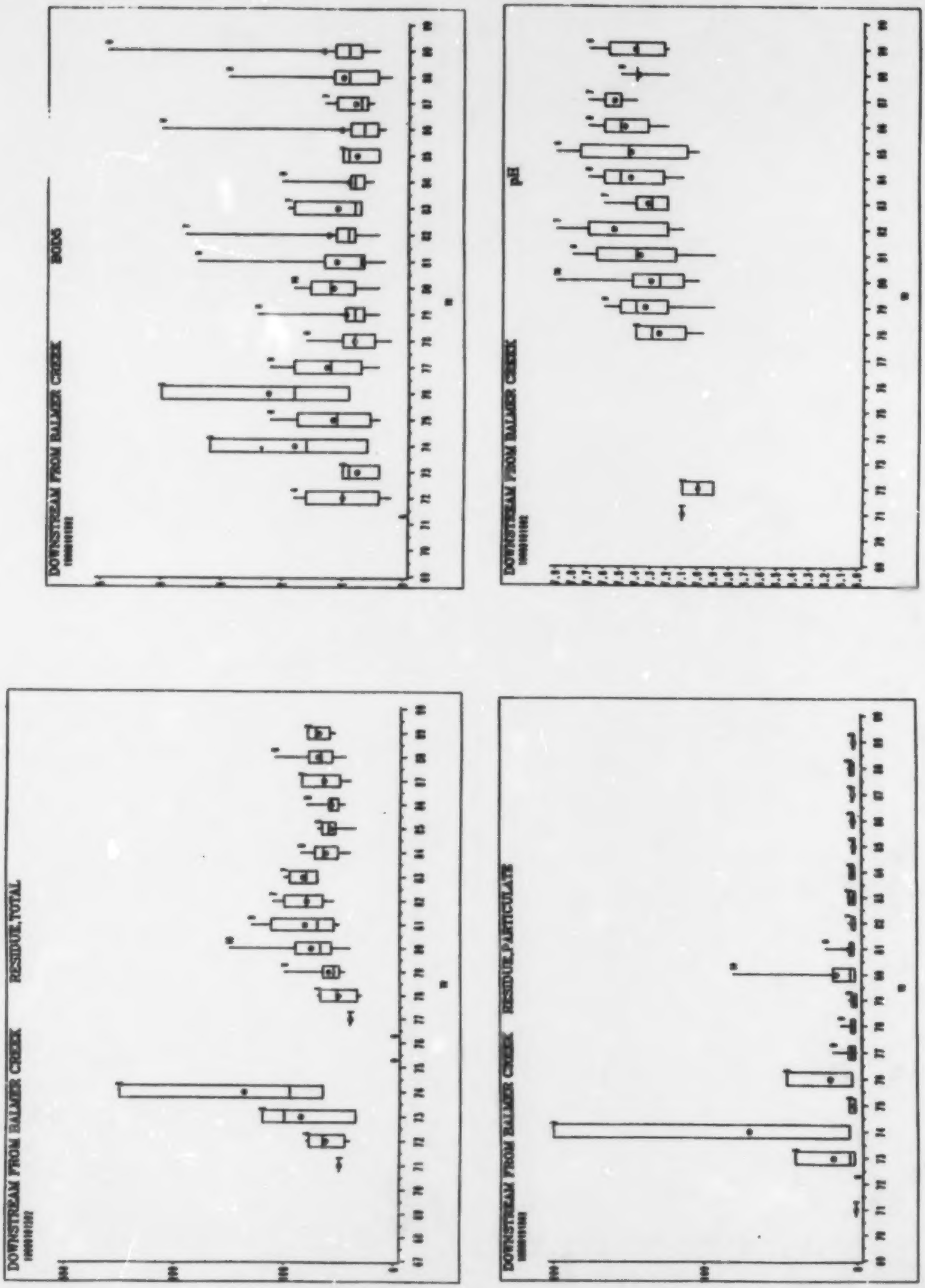

Fig. 158. Water quality in Chukuni R. D/S from Balmer Creek.

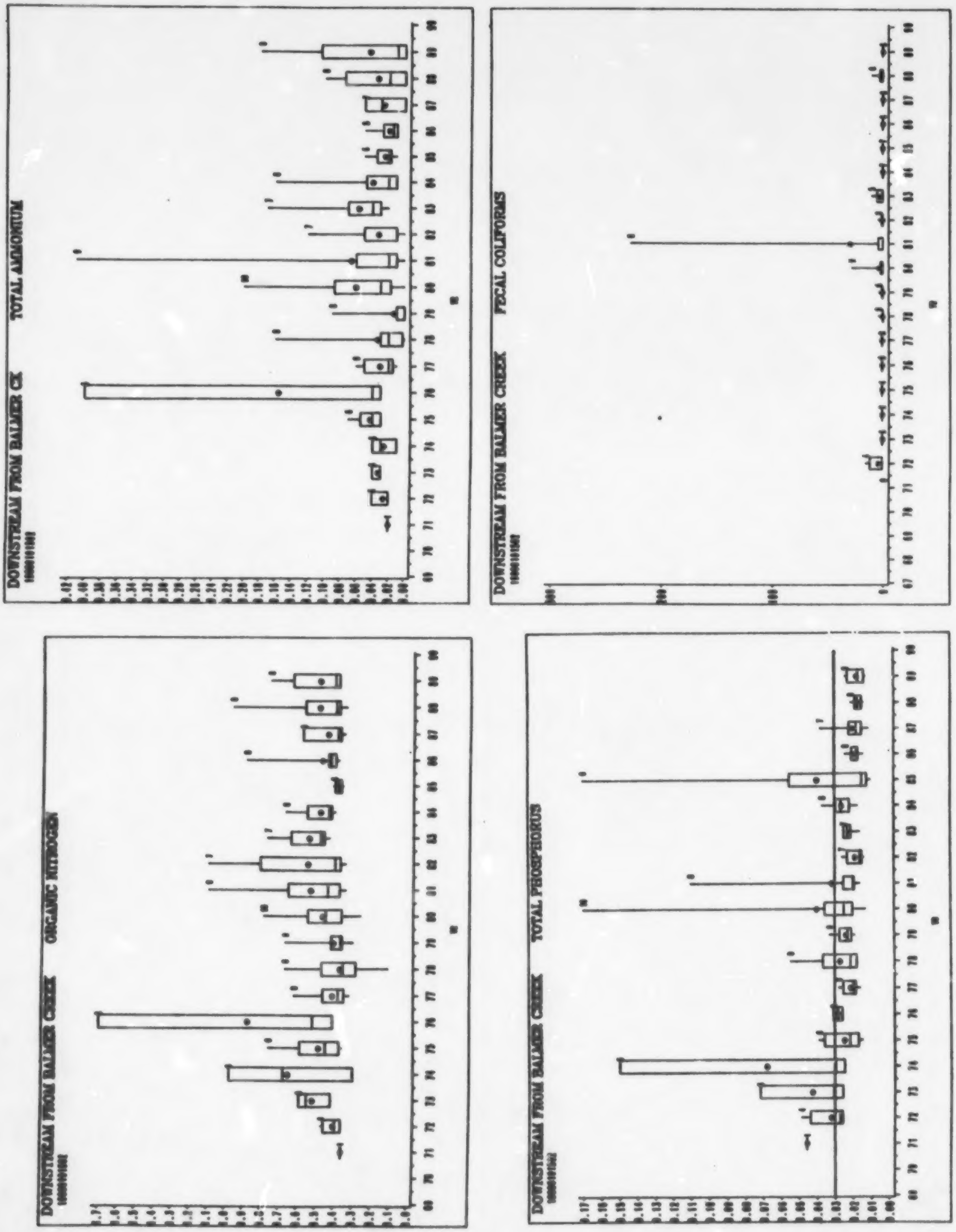

Fig. 159. Water quality in Chukuni R. D/S from Balmer Creek.

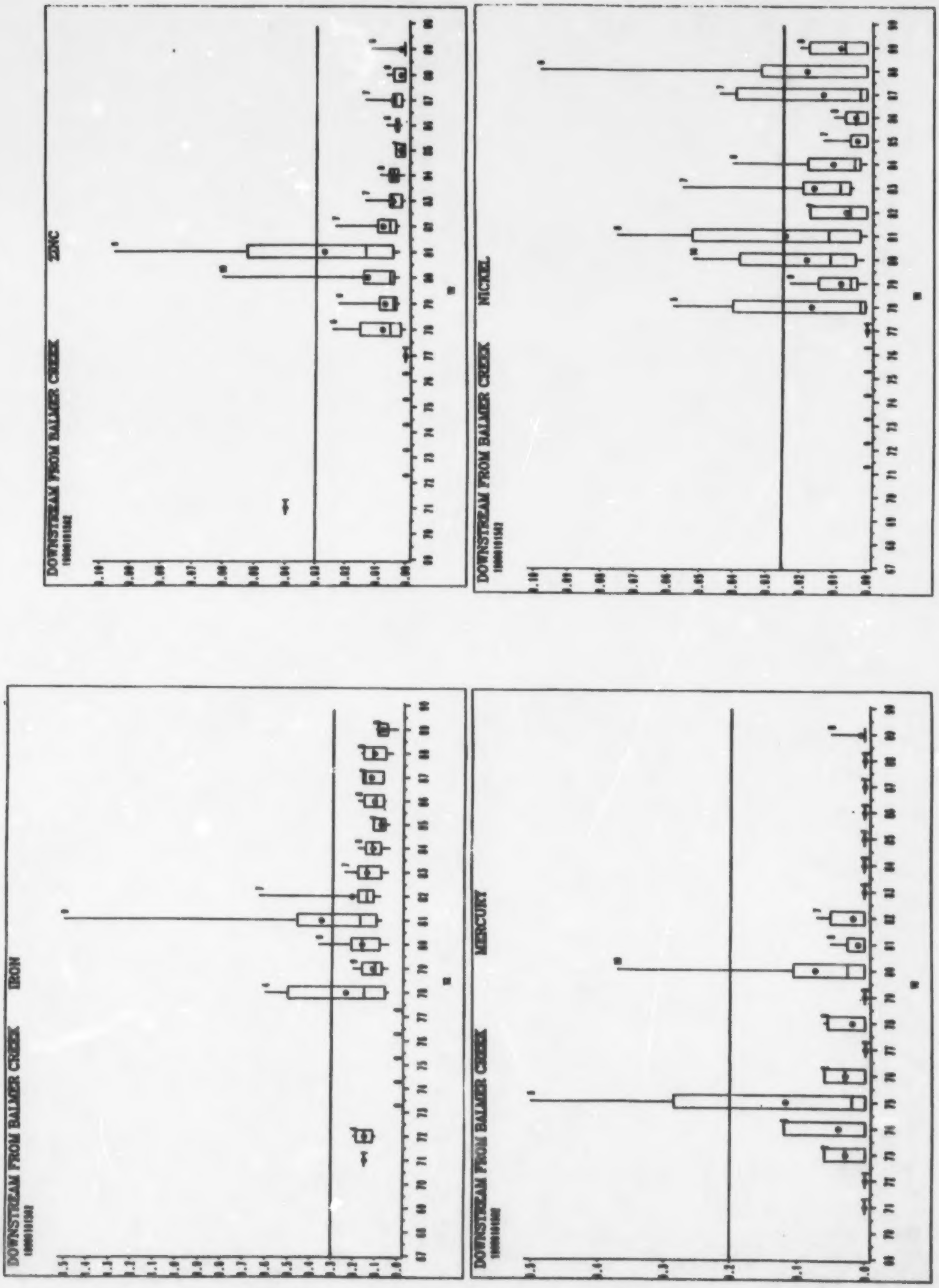

Fig. 160. Water quality in Chukuni R. D/S from Balmer Creek.

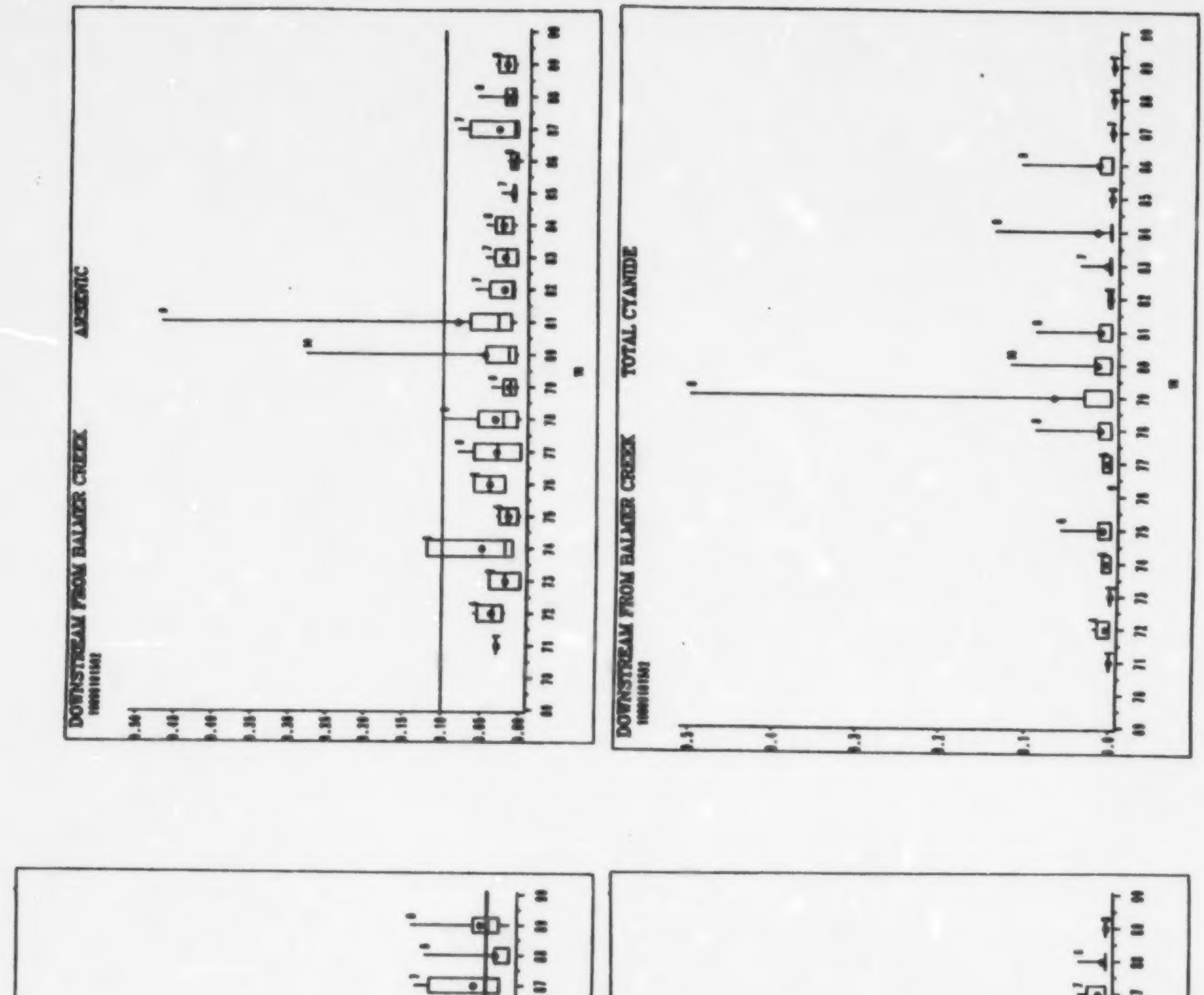

Fig. 161. Water quality in Chukuni R. D/S from Balmer Creek.

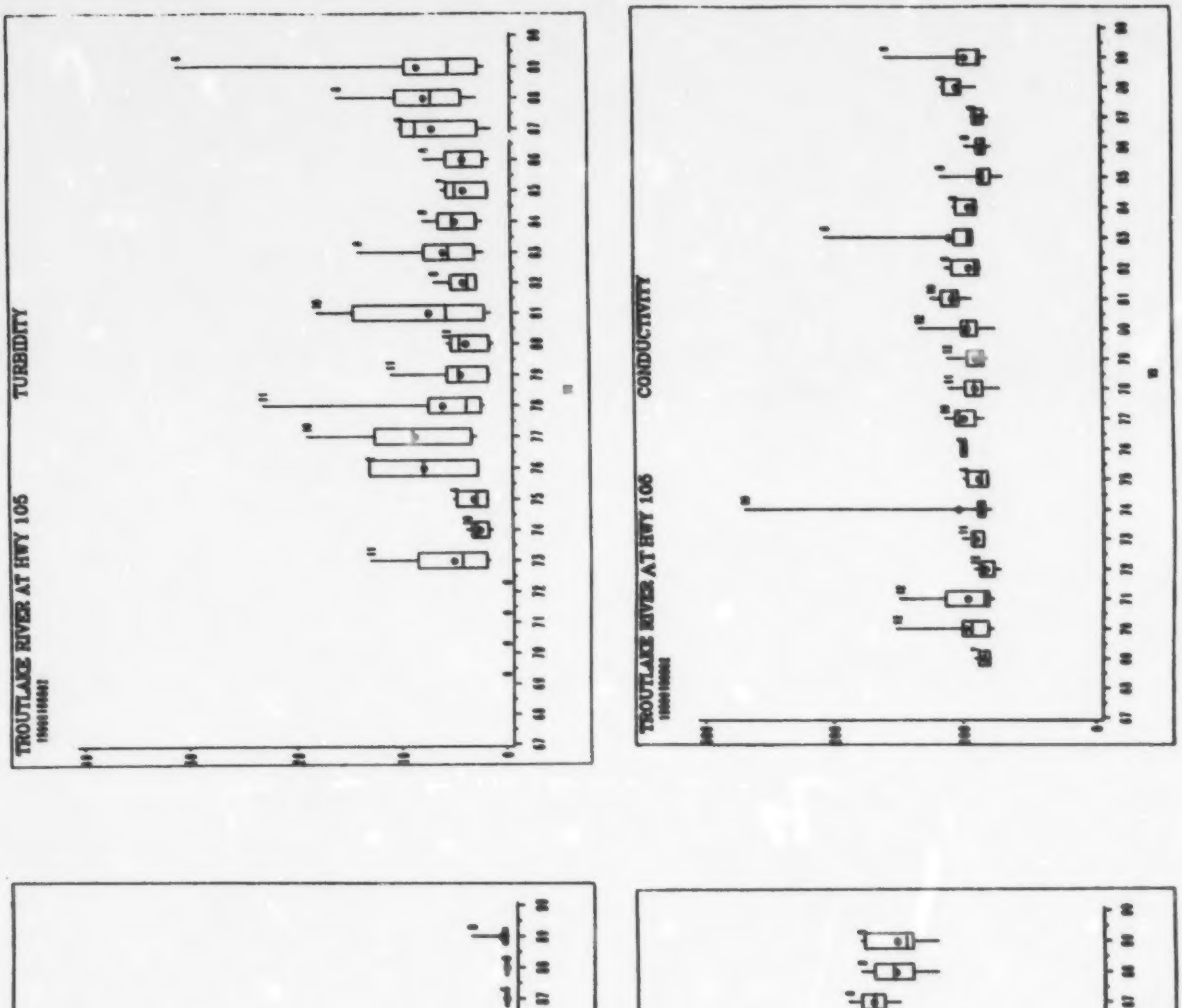

Fig. 162. Water quality in Troutlake River.

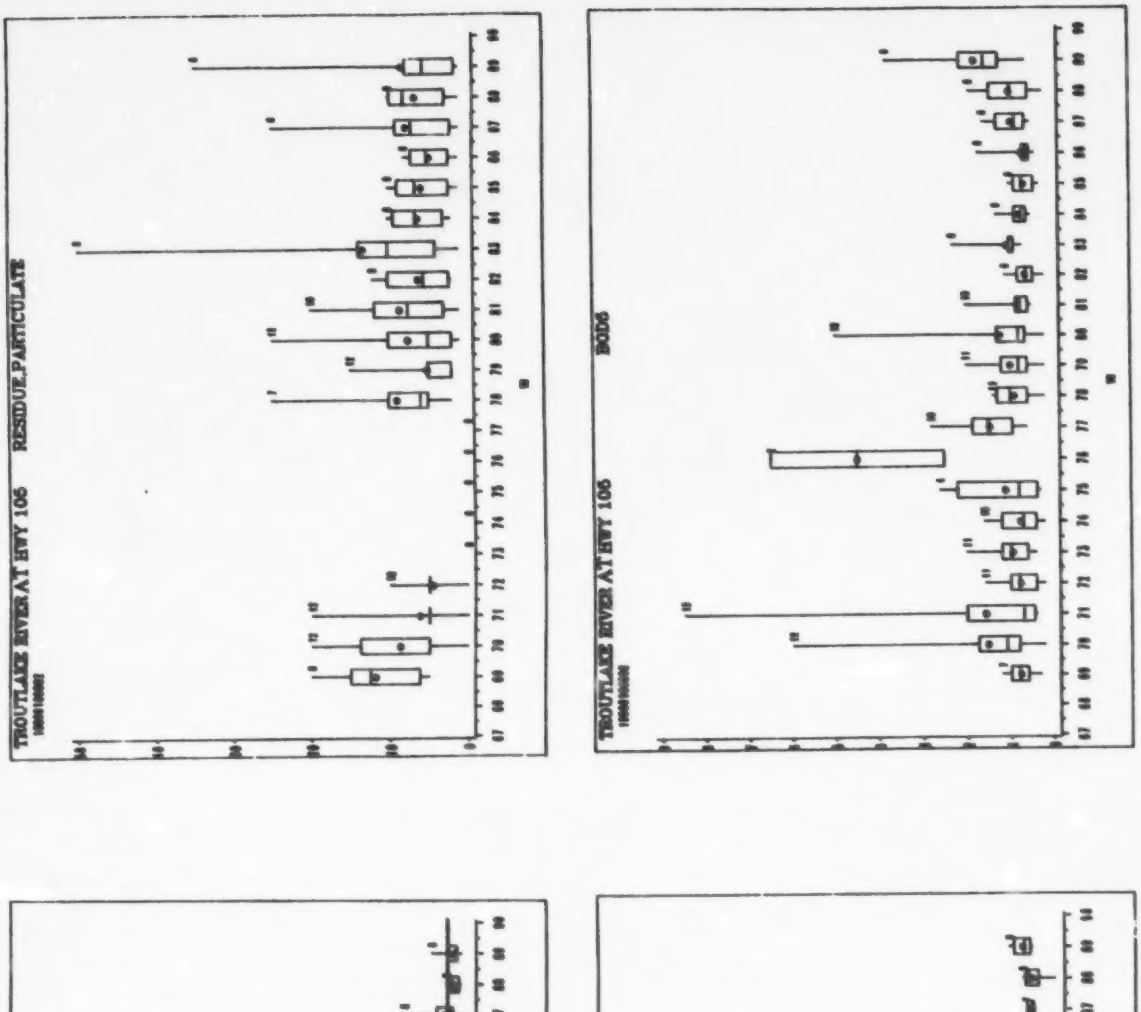

Fig. 163. Water quality in Troutlake River.

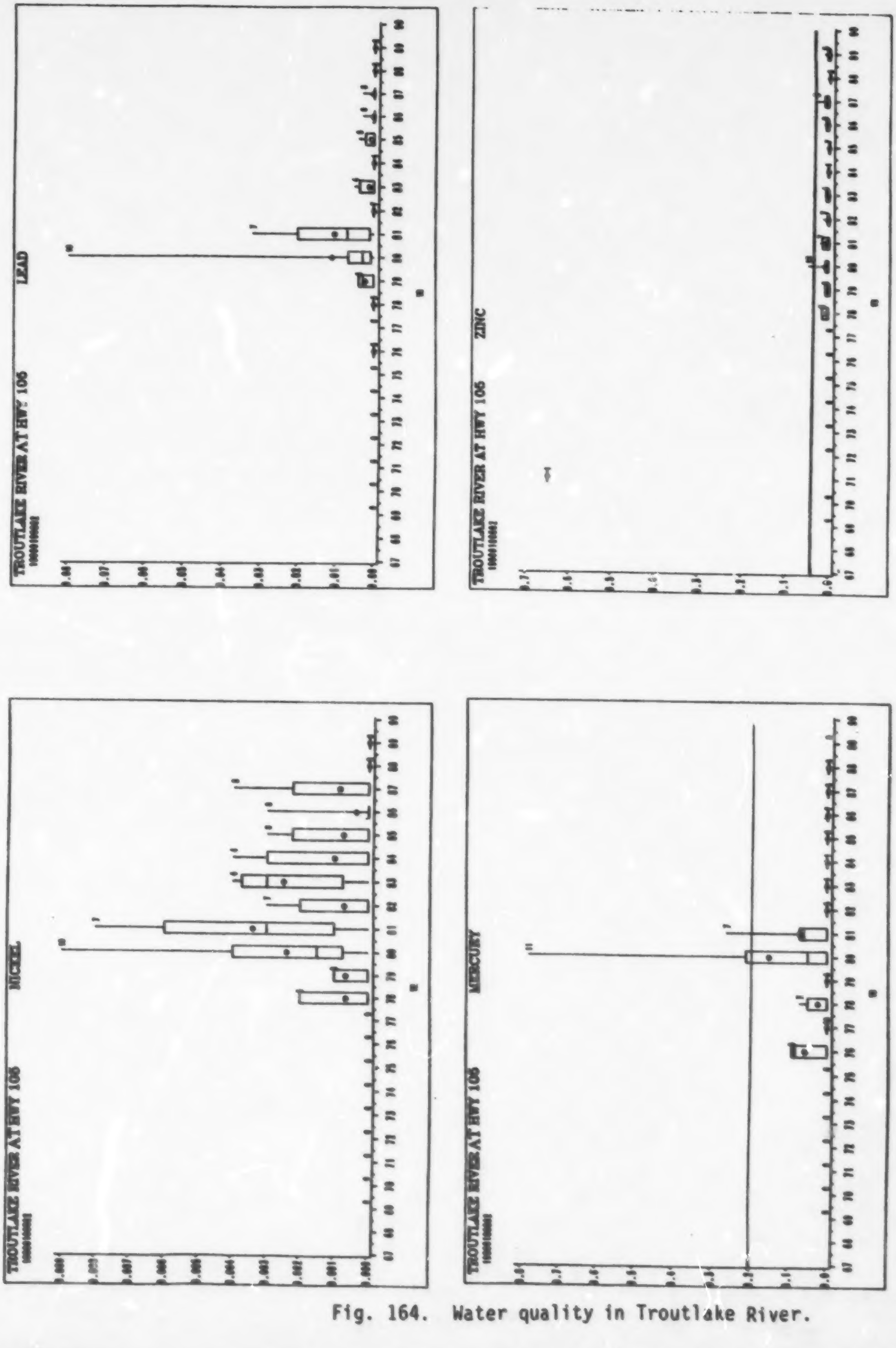

Fig. 164. Water quality in Troutlake River.

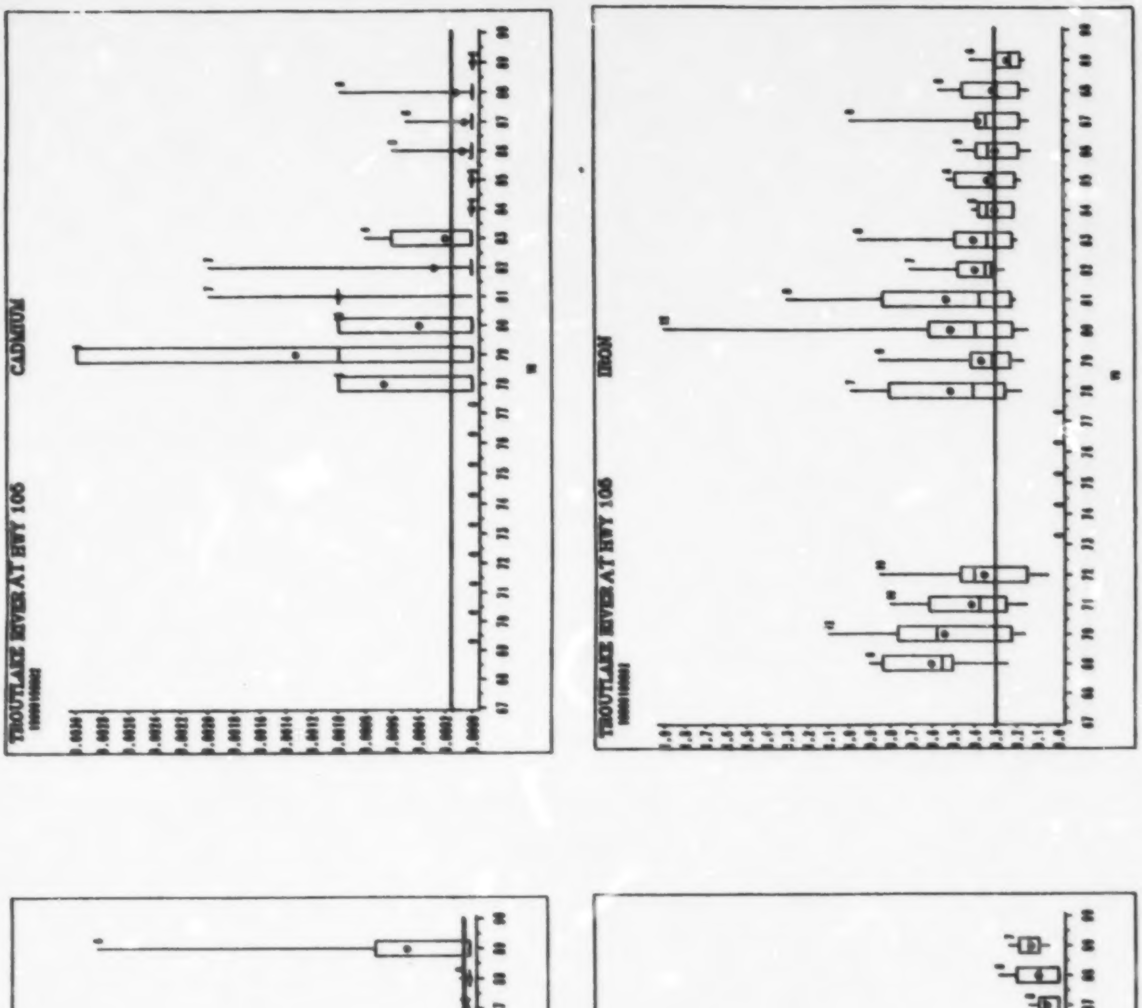

Fig. 165. Water quality in Troutlake River.

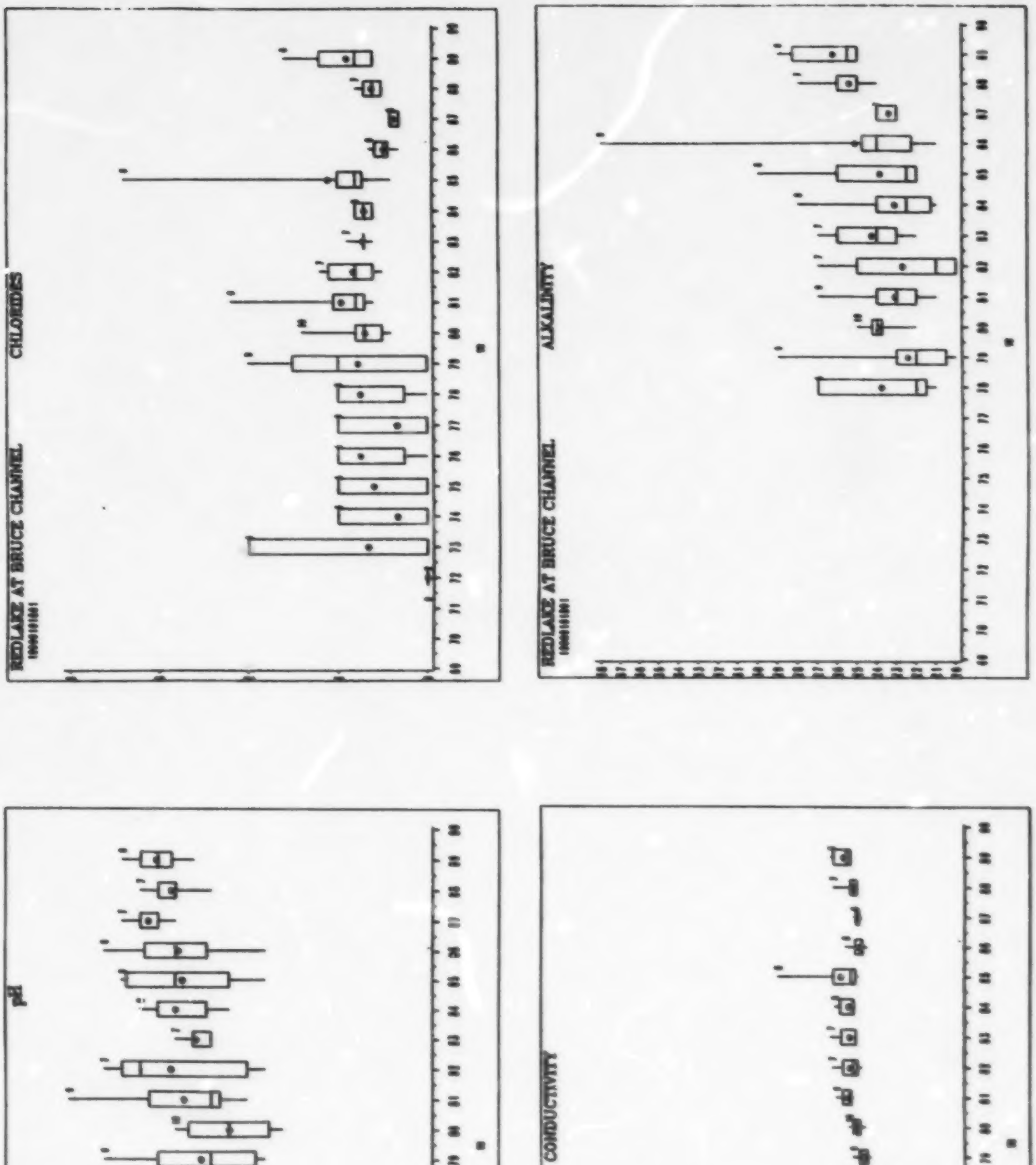

Fig. 166. Water quality in Red Lake - Bruce Channel.

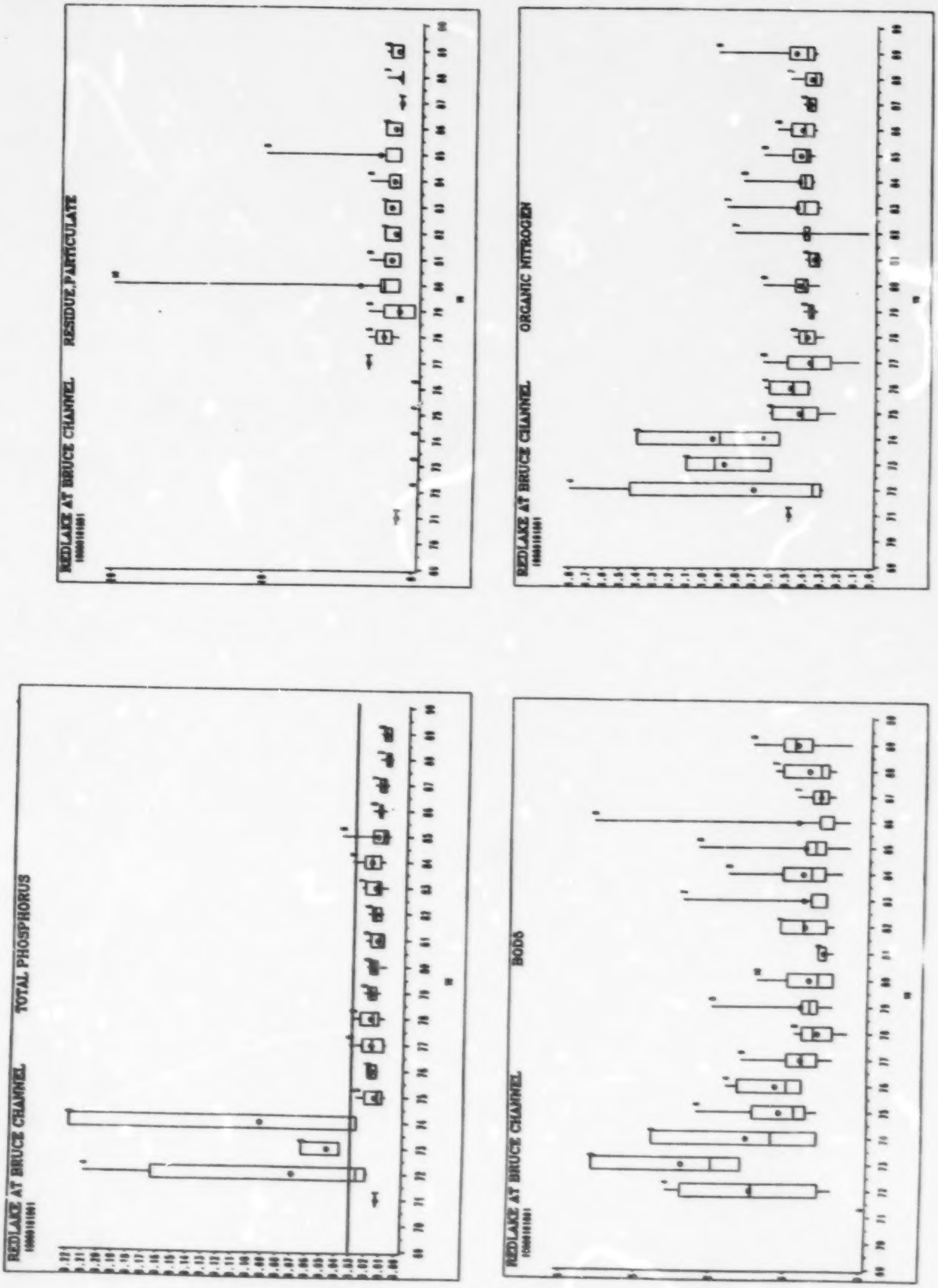

Fig. 167. Water quality in Red Lake - Bruce Channel.

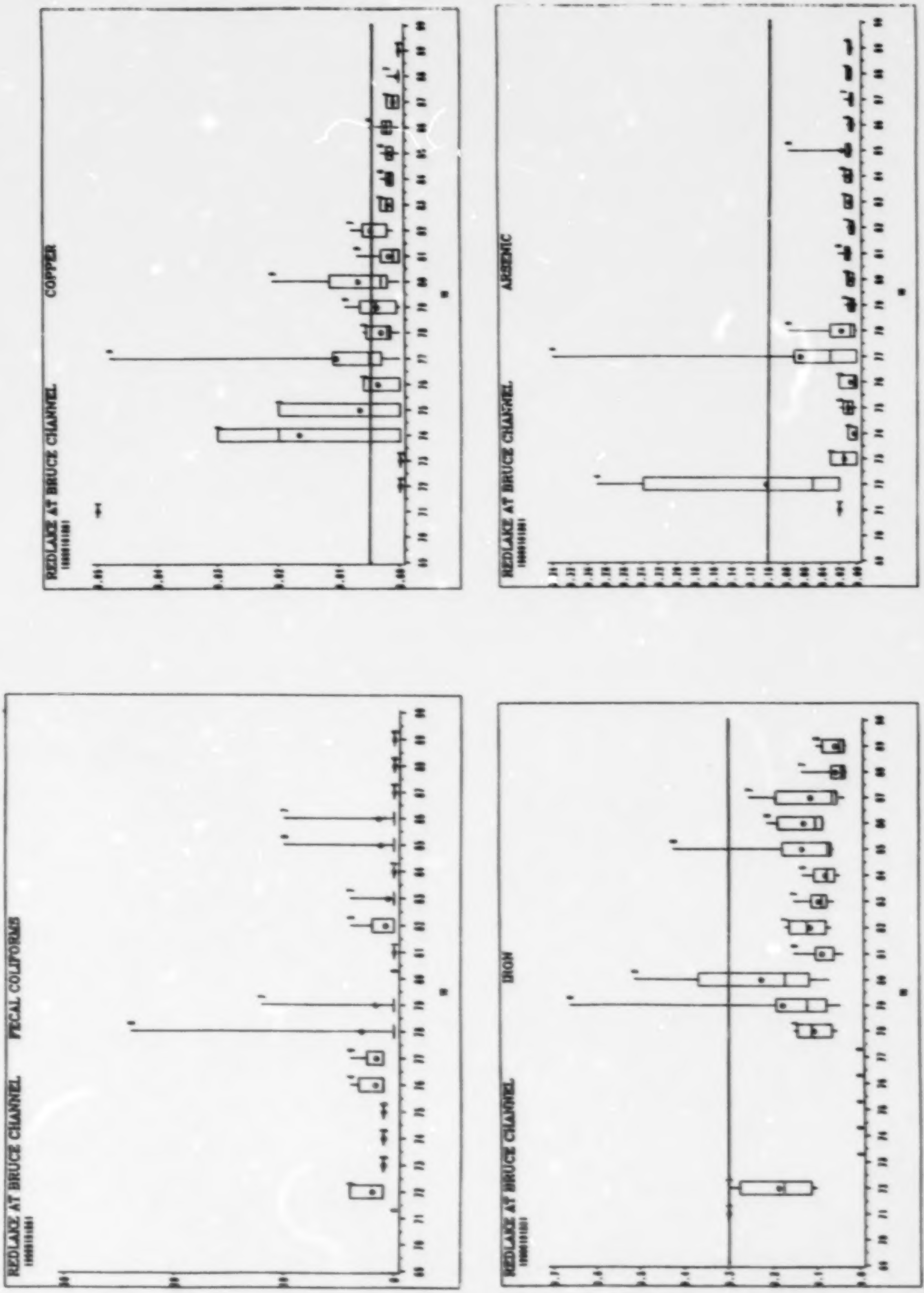

Fig. 168. Water quality in Red Lake - Bruce Channel.

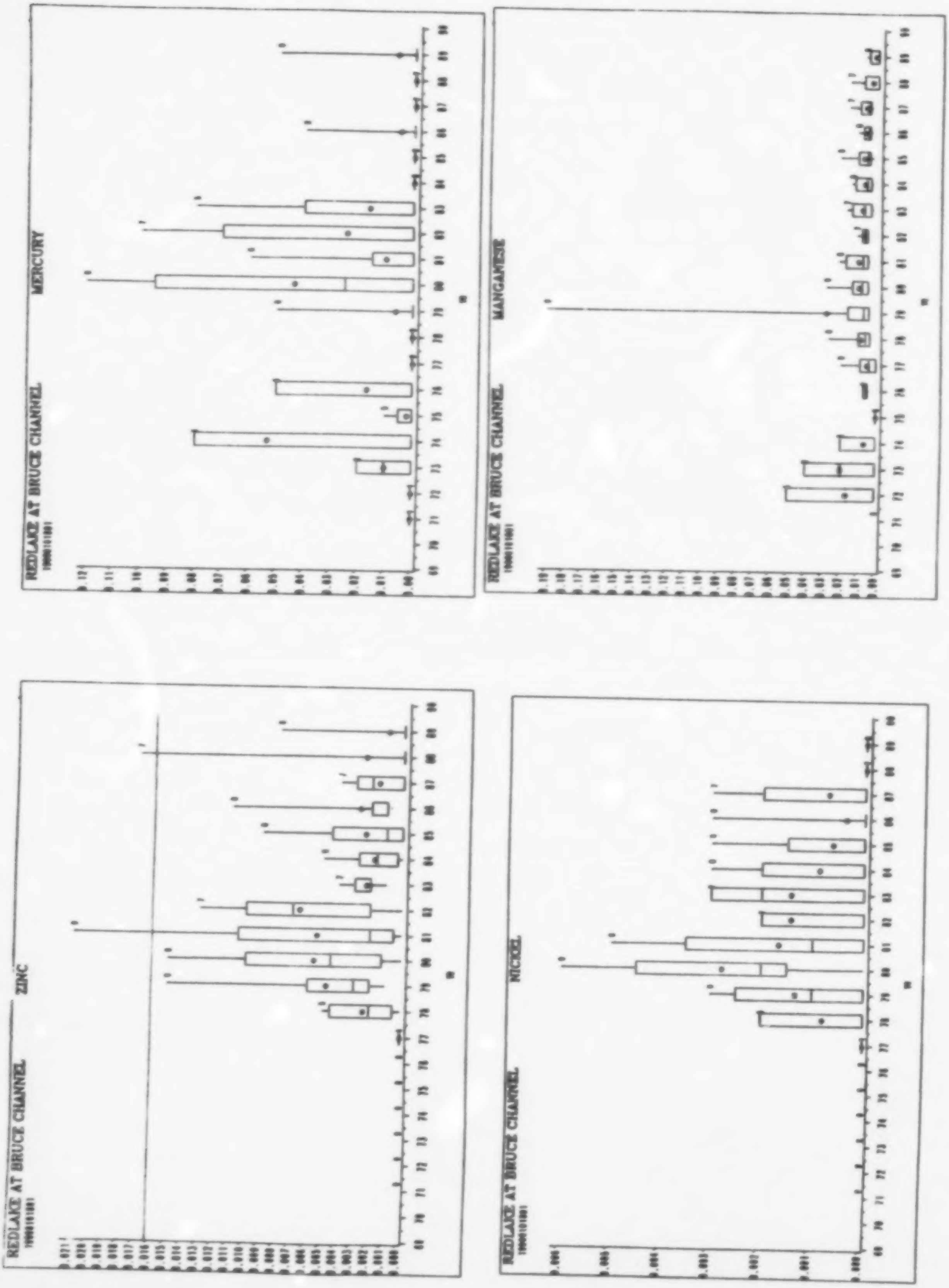

Fig. 169. Water quality in Red Lake - Bruce Channel.

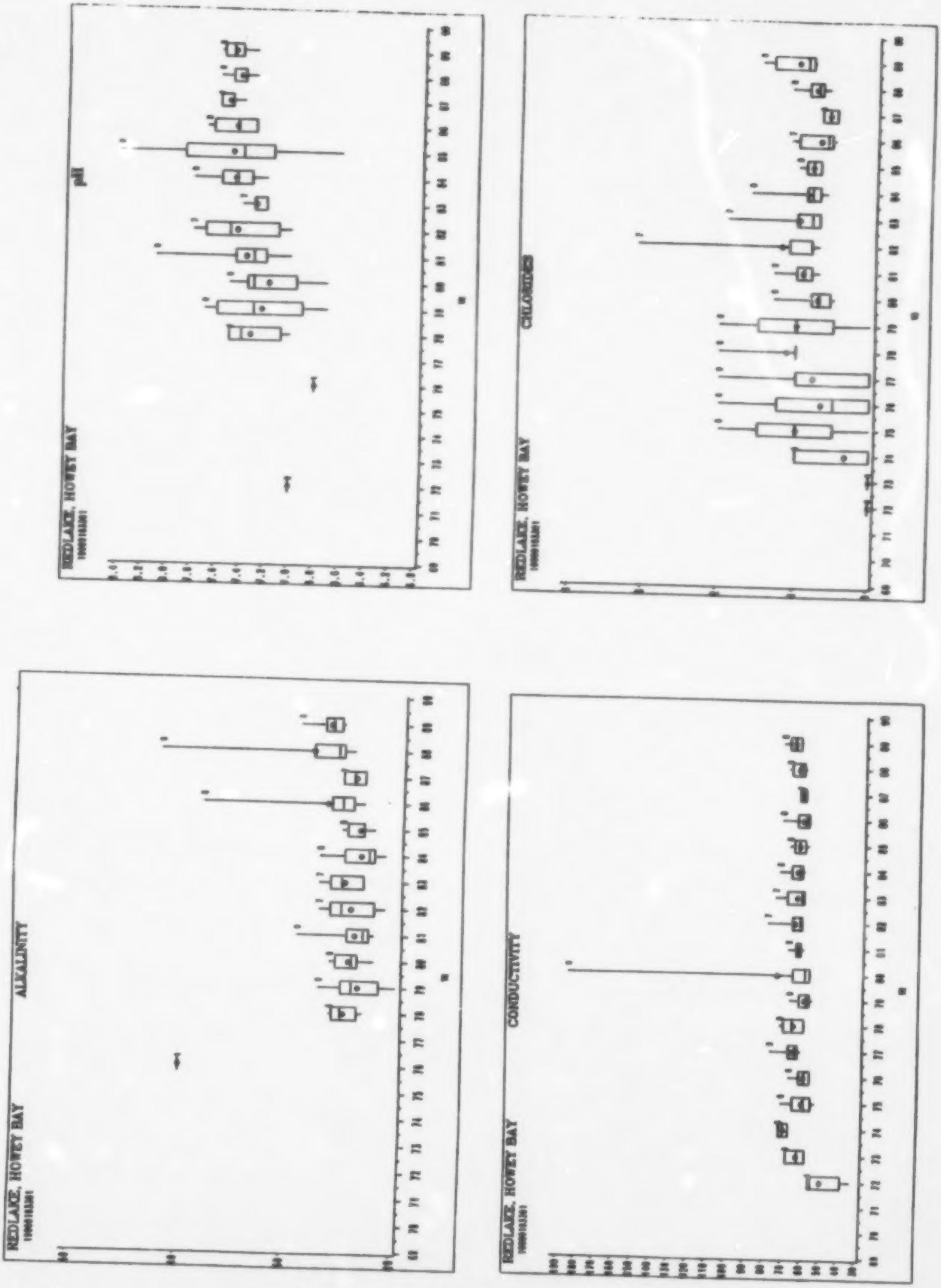

Fig. 170. Water quality in Red Lake - Howey Bay.

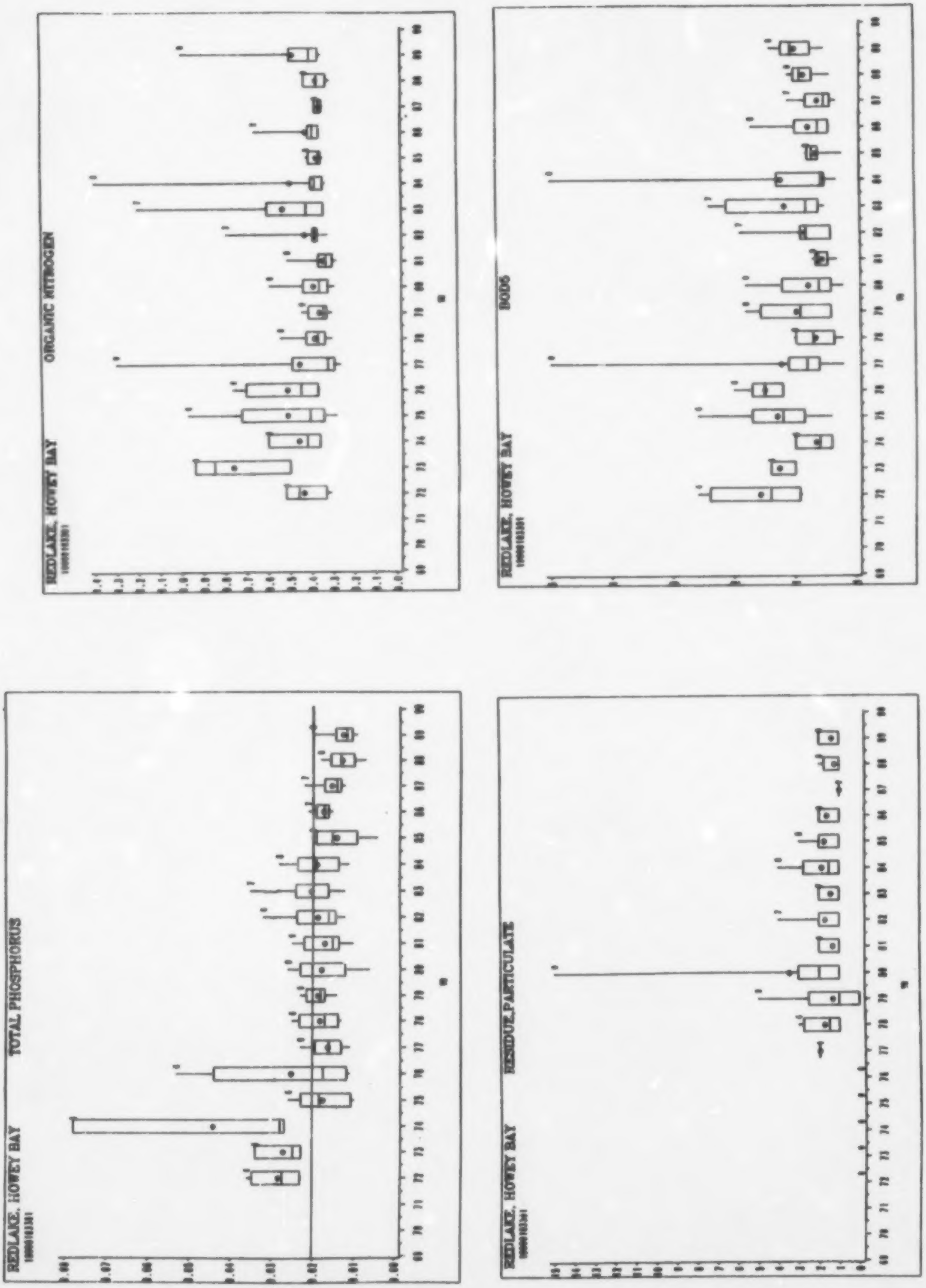

Fig. 171. Water quality in Red Lake - Howey Bay.

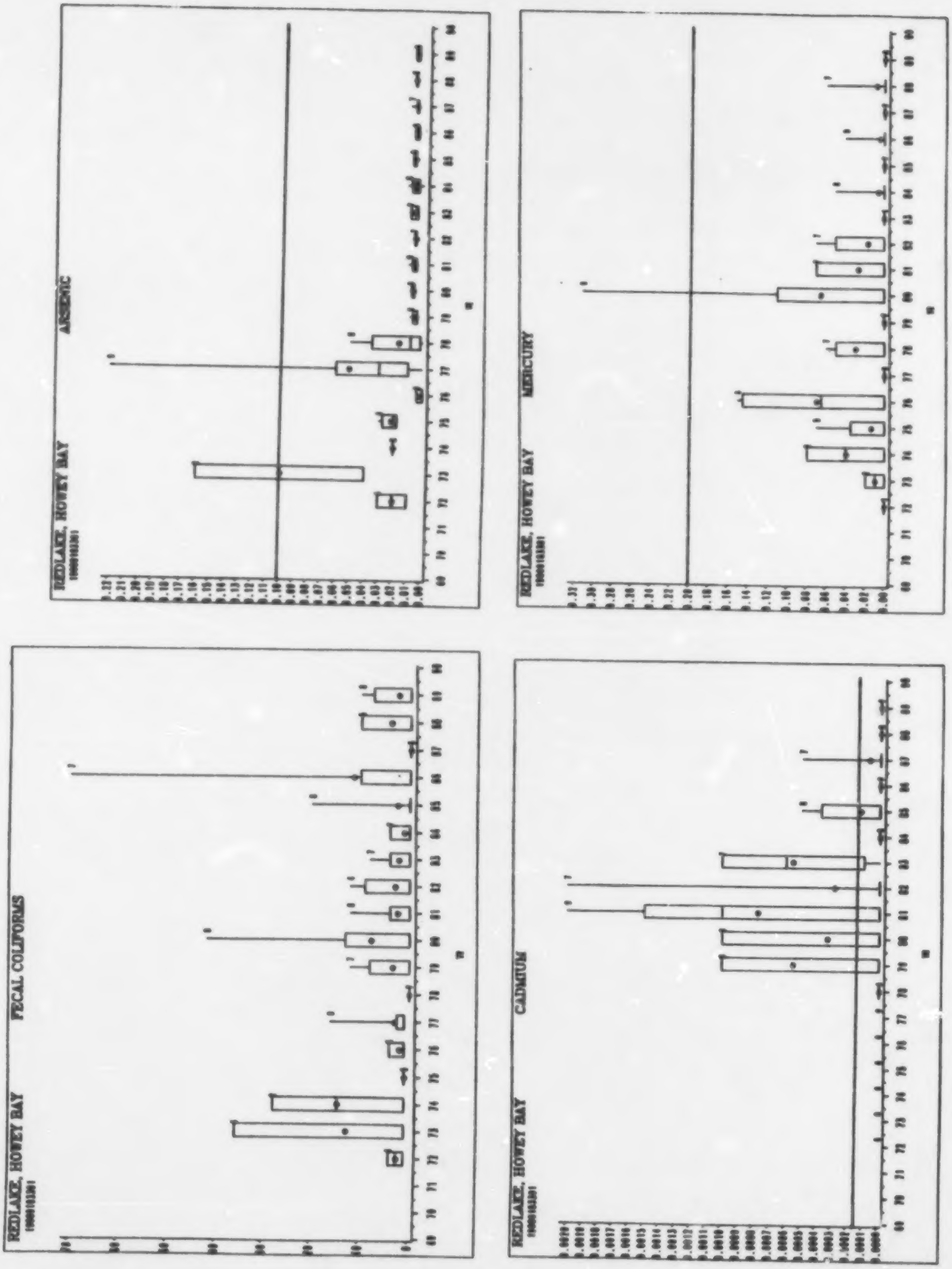

Fig. 172. Water quality in Red Lake - Howey Bay.

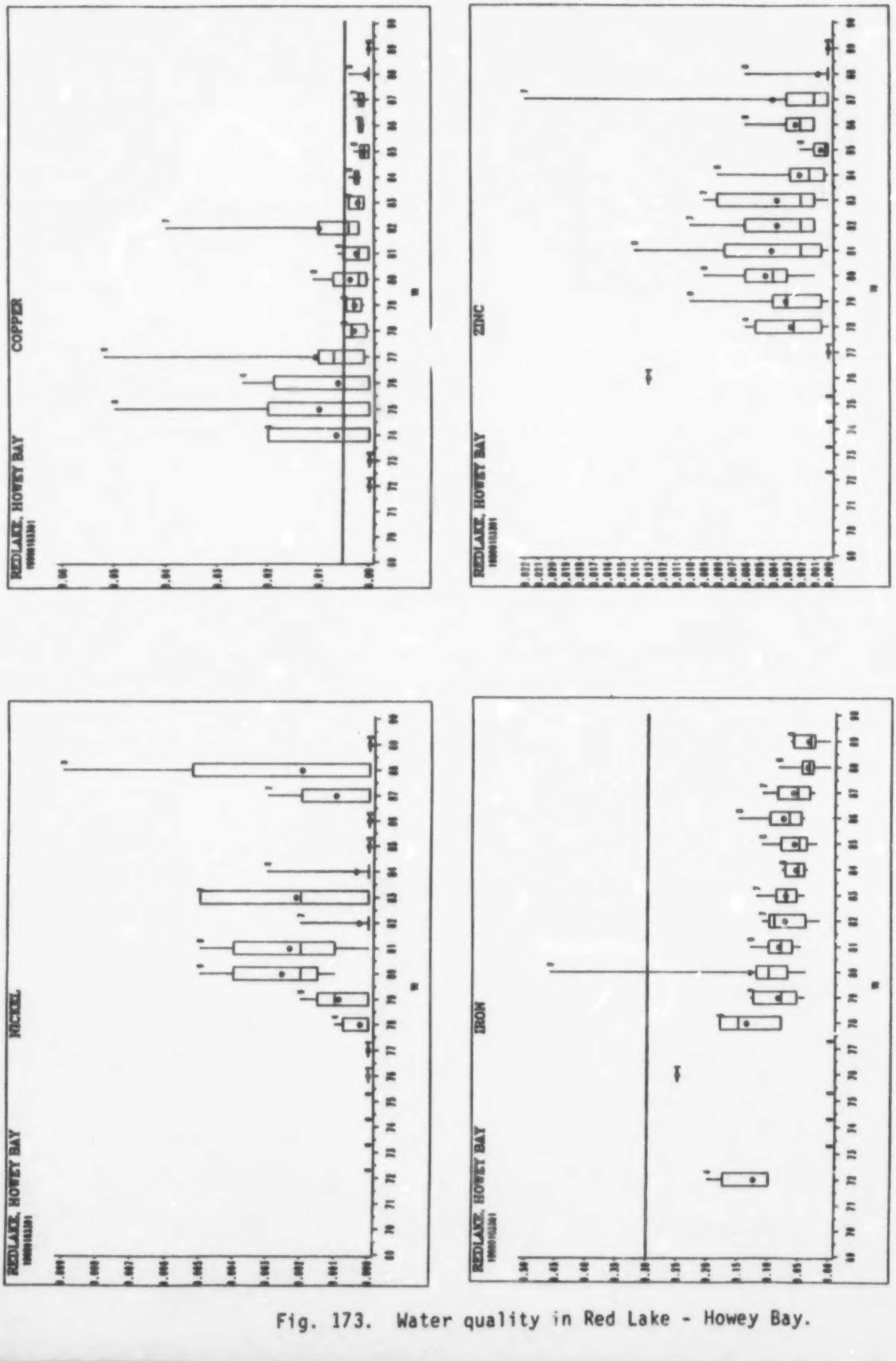

Fig. 173. Water quality in Red Lake - Howey Bay.

4.0 DISCUSSION

The monitoring network data provides a time-lapse picture of surface water quality in the Northwestern Region. Appendix 3 summarizes median values for all stations. The primary objective of this report is to document temporal variations and trends in conventional water quality parameters. In order to obtain a more complete understanding of the watersheds examined, particularly those impacted by industrial discharges, the reader is referred to further information from site specific studies referenced within this report.

To better convey the general character of water quality across the region, the discussion has been divided into four broad categories: background conditions, stations that show improvement in water quality, locations where water quality remains impaired and situations where water quality is being degraded.

4.1 Surface Water Quality

4.1.1 Background Conditions

Background conditions are reflected in the six IJC stations along the north shore of Lake Superior and nine other stations that are upstream of various point sources. Most of these are in relatively pristine environments with little or no upstream development. All exhibited low levels of dissolved substances, such as conductivity, hardness, chlorides, and sulphates. Background stations tended to have low coliform values with low to moderate levels of nutrients. Metals on some river systems were comparatively high. Alkalinities were relatively low, but there was no apparent reduction in pH over the period of record.

Another 15 stations monitor rivers further downstream of point sources where water quality reflects conditions of slight to moderate impairment. These stations showed higher levels of dissolved substances and nutrients, moderate to high levels of bacterial contamination, and metal levels that varied with the individual river system.

4.1.2 Improvements in surface water quality

Improvements in water quality can usually be attributed either to relocation or removal of point source or pollution control. Examples are summarized below.

In Thunder Bay, after the WWTP was relocated from a site on the McIntyre River to a site on the lower Kaministiquia River, most conventional parameters improved, some dramatically, without a comparable loss of water quality at the new site. Metal levels in the Troutlake River have fallen consistently since dredging stopped in 1979.

Improvements in total coliforms, BOD_5 and suspended solids were found downstream from the pulp and paper mills on the Kaministiquia and Wabigoon Rivers, and to a lesser extent, in Blackbird Creek, as a result of abatement measures. Coliform levels on the Rainy River and Winnipeg Rivers have improved. An overall reduction in bacterial contamination is evident across the region, despite the incomplete data set.

Mercury levels on the Wabigoon River and Blackbird Creek have declined since sources were eliminated. Some other metals (including zinc, copper, cadmium, and nickel) also were lower at several stations (Kaministiquia River, some north shore rivers, Thunder Bay rivers, and Wabigoon River) especially since 1986. This may reflect the low flows that have occurred in recent years. General declines in metal levels also were observed between the 1970's and the 1980's; these may reflect analytical improvements as well as improvements in water quality.

Other improvements can be attributed to widespread changes in the use and/or availability of a substance. Phosphorous levels declined on the Rainy and Wabigoon Rivers between 1968 and 1974 at upstream locations, and in Red Lake and the Chukuni River over the period of the report. This reflects a reduction in urban and cottage inputs.

4.1.3 Persistent water quality problems

Some of the improvements in water quality observed in the mid 1980's downstream from several industrial discharges disappeared after 1986. A series of dry years created low flow conditions that coincided with, and probably contributed to increases in parameters like BOD_5, conductivity and chlorides. This underlined the fact that while some improvements have been seen, water quality immediately downstream from major industrial developments remains degraded.

Rivers that carry large volumes of water, such as the Winnipeg River, showed the least impairment, despite reductions of flow. Blackbird Creek, where improvements may have occurred since 1989, typified the problems that arise when effluent is discharged into small receiving waters.

Other persistent problem areas included Rudder Creek, where upgrading of sewage treatment did not have the anticipated effect; and Fox Creek, where remediation of the long standing contamination has proven to be a slow process. Some improvements have been observed downstream from Mose Lake, especially in metals, but PWQO's were still exceeded. Contamination of the upper Black River also persisted at the station 50 kilometers downstream. Sulphates continued to rise, and zinc levels often were in exceedance, even in the 1988 and 1989, when levels had become undetectable at the upstream station.

4.1.4 Deteriorating water quality

In addition to parameters that resisted improvement in Rudder Creek there were several that deteriorated. Chlorides, conductivity and phosphorus all continued to rise.

It is evident that water quality in Balmer Creek is impaired and for some parameters may be getting worse. Of primary concern is that an already degraded system is displaying further deterioration at a distance from the point source. Increases in the Chukuni River in alkalinity, BOD_5, conductivity, chlorides, and several metals suggest that the impact may be extending downstream.

Hayward Creek also showed the effects of loadings from a lake unable to assimilate the contaminants discharged into it. Several conventional parameters were high and increasing; cyanide, ammonia and some metals exceeded the PWQO's soon after the mines went into production. A change in pH also was observed.

Other declines in water quality were relatively minor and/or isolated. These included increases in chlorides and conductivities in Thunder Bay rivers, which may reflect recent low water years. A slight increase in fecal coliforms was noted on the Current River during a period when levels declined on the McVicar Creek.

One apparent trend that will require further attention is the detection of low levels of mercury in some of the Thunder Bay and north shore rivers in the late 1980's. This finding is consistent with recent reports concerning the significance of atmospheric loading in determining mercury levels in Minnesota waters (Swain 1989).

4.2 Trends in Baseline Conditions

Several general patterns are apparent as a result of the preliminary analysis carried out in this report, and will be outlined below.

4.2.1 Extreme events

Data from the Pic River station also shed light on the nature of extreme events. A single sample, taken during an unusually high flood on June 26, 1984 provided maximum values for the following parameters: suspended solids, total phosphorus, organic nitrogen, copper, and chromium.

Such relationships between high flows, high suspended solids, and high metals may provide at least a partial explanation for the low levels of some metals observed on some Thunder Bay rivers in the late 1980's. In several cases low levels of suspended solids did coincide with low metal levels, but a detailed analysis has not been done.

4.2.2 Trends caused by long-term precipitation patterns

Long-term oscillations in pH and other measures of ionic concentration such as conductivity, alkalinity, hardness and chloride, seem to be related to precipitation. Although these patterns were apparent at most stations, the lack of confounding factors makes a more detailed evaluation possible at stations along the north shore of Lake Superior, i.e. Pic River, Black River, Little Pic River, Blackbird Creek, Nipigon River and Black Sturgeon River.

A visual inspection of the figures for the Black River (Figs. 37-39) suggests that correlations with discharge are more consistent than with precipitation, and that the parameters showing the highest correlation to discharge are conductivity, alkalinity, but not pH, and total phosphorus.

Most stations across the region exhibited increases in parameters such as conductivity in 1987, 1988, and/or 1989. Although water quantity was not the focus of this report, these data re-inforce the fact that even in an area such as northwestern Ontario that enjoys an abundance of clean water, the continued availability and, where regulation is in place, proper management of that supply, is necessary to ensure high water quality.

4.3 The PWQMN data base

The Provincial Water Quality Monitoring Network represents the backbone of Northwestern Region's water quality data base. It provides monthly water quality information in the vicinity of key municipal and industrial effluents. In addition, the Network addresses provincial obligations under the Great Lakes Water Quality Agreement, to provide information about contaminant loadings to Lake Superior from tributaries.

The PWQMN is most often used as an archive for broad-spectrum water quality information. In evaluating proposals for new industrial effluents, the PWQMN is generally the first place that Regional water quality and abatement staff look to obtain background water quality data. Likewise, most requests from individuals, industries, consultants, municipalities and government agencies for water quality information are answered by consulting PWQMN data. Through the years these data also have formed the bases of efforts by ministry staff to identify and deal with water quality problems. Current examples involve efforts to reduce the loading of contaminants to Balmer and Hayward Creeks.

The reliability of the data base is a reflection of the effort and ongoing commitment of field and laboratory staff. In working with the data one is struck by the high quality of the data for some core parameters: the large number of samples at most stations, the long term record, the relative infrequency of "fliers" (unexpectedly high or low data). This makes it possible to isolate and/or work around the irregularities that inevitably are present.

The greatest limitation of the data base stems from the changes that have been made through the years in an effort to reduce sampling and analytical costs. The record for some parameters is limited and/or sporadic. The reader is encouraged to note the sample sizes on which medians are based (Appendices 3.1 and 3.2) as well as the numbers of samples which were used to generate each boxplot.

Limited sampling is particularly apparent in the case of microbial data. The current level of sampling is adequate only to confirm that impairment exists, but does not allow one to distinguish between possible sources of contamination. A more detailed study would be required in order to delineate, for example, problems and/or improvements in the effluent from a WWTP that discharged downstream from a pulp mill. However, since the areas where swimming and other uses have been impaired due to bacterial contamination coincide with other water quality problems, the current level of sampling may be adequate until other parameters improve.

Another key element in interpreting and reporting these data is the analytical approach that has been used. In using the box plots, it was possible to identify central tendencies and variability, and some patterns, while ignoring fliers that can neither be explained nor discounted. It must be stressed that the information generated is indicative; the figures suggest likely trends and flag possible explanations. They are not definitive; further work might be required to confirm any trends or explanations that they suggest.

With this report and others, the water quality history recorded by the PWQMN is beginning to be mined for insights about trend and pattern in water quality. Water quality trends are often subtle and obscured by year to year variation and multi-year oscillations.

We now have the means to produce graphs of time series data that make the data more accessible to a range of users, and to maintain current PWQMN data files on the Northwestern Region minicomputer. Regional capabilities to effectively use PWQMN data are becoming more consistent with the high quality of the data base.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Improvement of receiving water quality has been most apparent under three scenarios. The most dramatic improvements occurred with the elimination of a waste discharge on decommissioning of a point source. Changes were also seen where the improvement in effluent quality was large and where the improvements in effluent quality were not offset by increases in effluent volumes. These improvements are contingent on flow conditions and the size of the effluent loading relative to the flow of the receiving stream.

Areas where water quality is continuing to deteriorate pose the greatest challenge and warrant vigorous efforts to stabilize and improve water quality.

The possibility that mercury levels within the Lake Superior Drainage Basin may be increasing requires further scrutiny.

The Provincial Water Quality Monitoring Network is an important tool in the efforts of the Ministry of the Environment to protect and improve water quality in northwestern Ontario. The extensive record of this sampling network provides a valuable archive of baseline conditions. The baseline data is essential for assessing future water quality impacts from natural processes and from urban and industrial development. Evaluation of current monitoring information facilitates timely identification of changes in water quality. The information from the network also permits the results of short, intensive surveys to be evaluated and linked to seasonal and year-to-year variations in water quality. The PWQMN should continue to be operated with annual reviews of station and parameter requirements.

6.0 LITERATURE CITED

Anonymous, 1986. The Griffith Mine, Red Lake Ontario. History and Disposition of facilities after closure. On file in NW Regional Office, OMOE. 19 pp.

Beak Consultants Ltd., 1988. Effluent Toxicity and Impacts on the Winnipeg River. A report for Boise Cascade Canada Ltd.

Beak Consultants Ltd., 1990. The Rainy River Water Quality Study. prepared for Boise Cascade Canada Ltd. and Boise Cascade Corporation.

Bonsor, N., N. McCubbin and J. B. Sprague. 1988. Kraft mill effluents in Ontario. Prepared for OMOE.

Bodo, B. 1989. Robust graphical methods for diagnosing trend in irregularly spaced water quality time series. Environmental Monitoring and Assessment 12:407-428.

Boomer, D. 1991. personal communication. Laboratory Services Branch, OMOE.

Boyd, Duncan 1990. Water and sediment quality in the Kaministiquia River delta and nearshore area of Lake Superior. Environment Ontario. Queen's Printer for Ontario, Toronto. 71 pp and Appendices.

Environment Canada. 1989. Historical Streamflow Summary, Ontario, to 1988. Inland Waters Directorate Water Survey of Canada.

Environmental Applications Group Ltd. 1989. Recent trends in effluent quality - Balmer Lake. prepared for Placer Dome Inc. and Dickenson Mines Ltd.

Fenton, M. 1991. personal communication. CPFP, Dryden.

Gadsby, J. W. and A. G. Chantler. 1988. Tailings Management Plan 1983 to 1993.

Gartner Lee Assoc. Ltd. 1985. A review of the Provincial Water Quality Monitoring Network. prepared for OMOE.

German, M. J. 1972. Effects of acid mine wastes on the chemistry and ecology of lakes in the Manitouwadge Chain, District of Thunder Bay. OWRC.

Helsel, D. R. 1990. Less than obvious; statistical treatment of data below the detection limit. Environmental Science and Technology. 24(12): 1766-1774.

International Rainy River Water Pollution Board. 1991. Water quality of the Rainy River. Fortieth Annual Status Report.

Klose, S. R. 1988. Kaministiquia River Water Quality Study Part 1: Waste Assimilation Capacity. OMOE.

Laine, A. O. 1991. Water quality in the Hemlo, Ontario, gold mining region. OMOE

Mierle, G. 1990. Aqueous inputs of mercury to Precambrian Shield lakes in Ontario. Environ. Toxicol. Chem. 9:843-852.

McLeod, A. I., K. W. Hipel and F. Camacho. 1983. Trend assessment of water quality time series. Water Resource Bull. 19(4):537-547.

Ontario Ministry of the Environment. 1972. Thunder Bay Regional water quality survey. 107 pp.

Ontario Ministry of the Environment. 1978. Water quality monitoring Northwestern Ontario. 41 pp.

Ontario Ministry of the Environment. 1979. Guidelines for environmental control in the Ontario mineral industry. 27 p.

Ontario Ministry of the Environment. 1983. Handbook of Analytical Methods for Environmental Samples. (update in preparation).

Ontario Ministry of the Environment. revised 1984. Water Management: Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment. 70 pp.

Ontario Ministry of the Environment. 1990a. Handbook of Analytical Methods for Environmental Samples. Thunder Bay Regional Laboratory.

Ontario Ministry of the Environment. 1990b. Northwestern Region User's Manual. Thunder Bay Regional Laboratory.

Ontario Ministry of the Environment. 1991. Provincial Water Quality Monitoring Network. Summary of total phosphorus data for the period from 1980 to 1990. Water Resources Branch.

Parks, J. W. 1988. Selected ecosystem relationships in the mercury contaminated Wabigoon-English River system, Canada, and their underlying causes. Water, Air and Soil Pollution 42:267-279.

Parks, J. W., D. Pugh and J. R. Barr. 1982. A chemical and biological assessment of waters impacted by active gold mining operations in the Red Lake Area. 48 pp.

Parks, J. W., C. Curry and D. Romani. 1991. Young northern pike, yellow perch and crayfish as bioindicators in a mercury contaminated watercourse. Environmental Monitoring and Assessment 16:39-73.

Reckhow, K. H. and S. C. Chapra. 1983. Engineering approaches for lake management, Vol. 1: data analysis and empirical modelling. Butterworth, Boston MA. 340 pp.

Remmen, S. 1991. personal communication. Thunder Bay Regional Laboratory.

Steedman, R. J. and B. A. Bodo. 1990. A SAS/GRAPH program to produce box-whisker diagrams from environmental data. OMNR manusacript report.

Tukey, J. W. 1977. Exploratory data analysis. Addison-Wesley, Reading, MA. 688 pp.

Swain, E. B. (ed.) 1989. Assessment of mercury contamination in selected Minnesota lakes and streams. Report to the Legislative Committee on Minnesota Resources. Executive Summary. Division of Water Quality. Minnesota Pollution Control Agency. 9 pp.

Appendix 1.1 List of PWQMN stations included in this report

STATION CODE	LOCATION	DESCRIPTION	PERIOD OF RECORD
01 0057 001 02	White River	At Highway 17	73-89
01 0057 002 02	Hayward Creek	D/S Molson & Lim Lakes on Forest Access	86-89
01 0060 001 02	Pic River	At Highway 17	73-89
01 0060 002 02	Black River	At Highway 17	73-89
01 0060 003 02	Black River	At Highway 614 South of Agonzon	76-89
01 0060 004 02	Black River	1 Mile below Outlet of Mose L. Ont. P&P Road	76-89
01 0060 005 02	Fox Creek	At Highway 614 Manitouwadge Lake	76-89
01 0060 006 02	Black River	Above Mose Lake on Ont. P&P Road	77-89
01 0060 007 02	Rudder Creek	3 Mi. West of Hwy. 614 on American Can Road	77-89
01 0060 008 02	Fox Creek	At Inflow to Manitouwadge Lake	80-89
01 0060 010 02	Cedar Creek	At Highway 17	84-89
01 0060 012 02	Cedar Creek	At Hydrometric Station	85-89
01 0067 001 02	Little Pic River	At Highway 17	73-89
01 0074 001 02	Blackbird Creek	At Highway 17 (Kimberly Clark Effluent)	73-87
01 0090 002 02	Nipigon River	At Highway 17, Nipigon	88-89
01 0092 001 02	Black Sturgeon River	At Highways 11 and 17	73-89
01 0104 001 02	Current River	At Cumberland Street Thunder Bay	73-89
01 0104 002 02	Current River	At Highways 11 and 17 Thunder Bay	66-89
01 0105 001 02	McVicar Creek	At Cumberland Street Thunder Bay	68-89
01 0106 001 02	McIntyre River	At Hammond Avenue	66-89
01 0106 002 02	McIntyre River	Highways 11 & 17 City of Thunder Bay	68-81
01 0107 001 02	Neebing River	at 110th Avenue	72-89
01 0107 002 02	Neebing River	Hwys. 11 & 17 West of Maplewood Side Road	68-81
01 0107 003 02	Neebing-McIntyre River	Diversion, replaces 0106-001 and 0.107-001	68-89
01 0108 001 02	Kaministiquia River	At Highway 61B Thunder Bay	82-89
01 0108 002 02	Kaministiquia River	Upstream of Highway 61 Bridge	66-68/72-89
01 0108 003 02	Kaministiquia River	Middle of Turning Basin	66-89
01 0108 004 02	Kaministiquia River	Near Mouth	68-89
01 0108 005 02	Kaministiquia River	At Mission River Junction	78-89
01 0109 001 02	McKellar River	At 104th Avenue	68-89
01 0109 002 02	McKellar River	Near Mouth	66-68/72-89
01 0110 001 02	Mission River	Near Mouth	68-89
19 0001 001 02	Winnipeg River	At First CPR Br. West of Main St. Kenora	68-89
19 0001 002 02	Winnipeg River	Northwest of Old Fort Island	68-72/75-89
19 0001 003 02	Rainy River	Downstream of Emo	68-72/75-89
19 0001 004 02	Rainy River	Toll Bridge Fort Frances	68-72/75-89
19 0001 005 02	Wabigoon River	Upstream from Canadian Pacific Forest Prod.	68-88
19 0001 006 02	Wabigoon River	Dnstr. of C.P.F.P., Golf Course Br.	68-72/75-89
19 0001 008 02	Troutlake River	At Highway 105	68-72/75-89
19 0001 009 02	Rainy River	Dnstr. from Confluence with Baudette River	69-72/75-89
19 0001 010 02	Rainy River	Upstr. from Confluence with Baudette R.	69-72/75-89
19 0001 011 02	Rainy River	Above Emo	69-72/75-89
19 0001 012 02	Rainy River	Downstream from Fort Frances	69-72/75-89
19 0001 015 02	Chukuni River	Downstream from Balmer Creek	69-72/75-89
19 0001 016 02	Balmer Creek	At Balmer Lake Outlet	71-89
19 0001 018 01	Red Lake	In Bruce Channel at Ferry Crossing	71-89
19 0001 032 02	Balmer Creek	500 Feet Upstream of Chukuni River	72-89
19 0001 033 01	Howey Bay	500 Feet from Shore, Red Lake	72-89
19 0001 035 02	Wabigoon River	At Minnitaki Sideroad	72-89
19 0001 036 01	Wabigoon River	Highway 609 near Quibell	80-89
19 0001 038 02	Wabigoon River	Highway 17	80-89
			87-89

Appendix 1.2 List of discontinued and excluded PWQMN stations in Northwestern Region

STATION CODE	LOCATION	DESCRIPTION	PERIOD OF RECORD
01 0000 001 01	Lake Superior	Inside Eastern Gap Thunder Bay	68-89
01 0000 002 01	Lake Superior	Off Mouth of Kaministiquia River	68-89
01 0000 003 01	Lake Superior	Near Pulp Mill Mission Bay Thunder Bay	69-89
01 0000 004 01	Lake Superior	Near Prov.Mill Eastern Gap Thunder Bay	69-89
01 0000 005 01	Lake Superior	Near Abitibi Thunder B. Paper Mill Slip	72-89
01 0000 006 01	Lake Superior	At Atibibi Thunder Bay Paper Mill Ditch	77-89
01 0000 007 01	Lake Superior	5.5 Mi. East of Welcome Isl. Lighthouse	78-89
01 0000 008 01	Lake Superior	5 Mi. SE of Welcome Islands	77-77
01 0000 009 01	Lake Superior	6 Mi. SE of Angus Island Lighthouse	77-77
01 0000 010 01	Lake Superior	2.5 Km East of McKellar Island	78-89
01 0000 011 01	Lake Superior	2 Km East of Northern Wood Preserves	78-89
01 0000 012 01	Lake Superior	East of Mission Bay Dredge Disposal Fac.	86-89
01 0000 013 01	Lake Superior	600 Meters N of Red Rock WTP Intake	86-89
01 0000 014 01	Nipigon Bay	100 Meters SE of Domtar Mill Outfall	86-89
01 0000 015 01	Lake Superior	2000 Meters NE of Burnt Island	86-89
01 0000 016 01	Jackfish Bay	900 Meters Out From CPR Tunnel	86-89
01 0000 017 01	Jackfish Bay	100 Meters from Mouth of Blackbird Ck.	86-89
01 0000 018 01	Jackfish Bay	600 Meters from Mouth of Blackbird Ck.	86-89
01 0000 019 01	Lake Superior	100 Meters West of Hawkins Is.	86-88
01 0000 020 01	Lake Superior	100 Meters East of James River Marathon	86-89
01 0057 003 02	White River	U/S White River	78-
01 0057 004 02	White River	D/S White River	78-
01 0060 009 02	Little Black River	At Highway 17	84-84
01 0060 011 02	Wabikoba Creek	At Highway 17	84-84
01 0068 001 02	Dead Horse Creek	At Highway 17	80-84
01 0070 001 02	Prairie River	At Highway 17	73-75
01 0073 001 02	Steel River	At Highway 17	73-75
01 0074 002 02	Blackbird Creek	At Highway 17, replaced -0074-001	88-89
01 0075 001 02	Aguasabon River	At Highway 17 Terrace Bay	73-75
01 0075 002 02	Aguasabon Diversion	At Aguasabon Hydro Plant	73-78
01 0078 001 02	Whitesand River	U/S of Minova Mine	73-75
01 0078 002 02	Whitesand River	At Hydrometric Station	88-89
01 0078 003 02	Whitesand River	Below CPR Bridge	88-89
01 0080 001 02	Pays Plat River	At Highway 17	88-89
01 0081 001 02	Gravel River	At Highway 17	73-75
01 0086 001 02	Jackpine River	At Highway 17	73-75
01 0088 001 02	Jackfish River	At Highway 17	73-75
01 0090 001 02	Nipigon River	At Bridge Cameron Falls	69-84
01 0094 001 02	Wolf River	At Highways 11 and 17	73-75
01 0095 001 02	Coldwater Creek	At Highways 11 and 17	73-75
01 0100 001 02	Pearl River	1.5 Miles SE of Pearl	73-75/77-77
01 0103 001 02	Mackenzie Creek	At Highways 11 and 17	73-75
01 0108 006 02	Kaministiquia River	U/S CPFP	85
01 0108 007 02	Kaministiquia River	D/S CPFP	85
01 0108 008 02	Kaministiquia River	D/S Turning Basin	85
01 0108 009 02	Kaministiquia River	D/S 61B	85
01 0108 010 02	Kaministiquia River	Tarbutt Street	85
01 0108 011 02	Kaministiquia River	U/S IGP	85
01 0108 012 02	Kaministiquia River	D/S IGP	85
01 0108 013 02	Kaministiquia River	U/S STP	85
01 0108 014 02	Kaministiquia River	U/S STP	85
01 0108 015 02	Kaministiquia River	U/S STP	85
01 0115 001 02	Cloud River	At First Bridge above Cloud Bay	73-75
01 0116 001 02	Pine River	At Highway 61	73-75
01 0117 001 02	Pigeon River	At Highway 61, Pigeon River	73-78
19 0001 007 02	English River	At Manitou Falls	68-83
19 0001 013 02	Rainy River	Downstream from Fort Frances, Centre	69-72/75-81
19 0001 014 02	Rainy River	Downstream from Fort Frances, South	69-72/75-81
19 0001 017 02	Saib Lake Creek	At Saib Lake Outlet	71-84
19 0001 019 02	Quetico River	Near Wawa Island	71-71

Appendix 1.2 Cont'd ...

STATION CODE	LOCATION	DESCRIPTION	PERIOD OF RECORD
19 0001 020 02	Namakan River	At Lac la Croix	71-71
19 0001 021 02	Maligne River	Upstream from Minn Lake Outlet	71-71
19 0001 022 02	Minn Lake Outlet	Outlet to Martin Bay	71-71
19 0001 023 02	Tuck River	Above Moose Bay	71-71
19 0001 024 02	Mid Roland Lk. Out	At Roland Lake Outlet	71-71
19 0001 025 02	Agnes Lake Inlet	Louisa Falls	71-71
19 0001 026 02	Agnes River	At Outlet of Agnes Lake West Channel	71-71
19 0001 027 02	Namakan River	At Outlet of Sheridan Lake	71-71
19 0001 028 02	Maligne River	At Outlet of Cache Bay Silver Falls	71-71
19 0001 029 02	Wawiag River	At Mouth Kawa Bay McKenzie Lake	71-71
19 0001 030 02	Maligne River	At Outlet of Pickerel Lake	71-71
19 0001 031 02	Little Pickerel R.	At Highway 11 Inlet to French Lake	71-71
19 0001 034 01	Rainy Lake	Highway 11 Noden Causeway	75-77
19 0001 037 02	Snib Creek	At Mouth St. Paul's Bay	82-84
19 0008	Severn River	8 remote stations	83-89
19 0018	Winisk R. System	2 remote stations	83-89
19 0043	Attawapiskat R.	1 remote station	83-89
19 0053	Albany R. System	2 remote stations	83-89

Appendix 1.3 Summary of hydrological data from Environment Canada (1989) stations nearest to PWQMN stations

Station Code	Name	Environment Canada Code	Drainage Area (km^2)	Total Discharge (annual mean) ($decameters^3$)
01-0057-001-02	White River	02BC004	4170	1.66×10^6
01-0060-001-02	Pic River	02BB003	4270	1.65×10^6
01-0060-002-02	Black River	02BB002	1980	0.86×10^6
01-0060-012-02	Cedar Creek	02BB004	201	0.74×10^5
01-0074-001-02	Little Pic River	02BA003	1320	0.49×10^6
01-0074-001-02	Nipigon River at Pine Portage*	02AD008	24600	11.1×10^6
01-0092-001-02	Black Sturgeon R.	02AC002	2980	0.75×10^6
01-0106-002-02	McIntyre River	02AB016	145	0.46×10^5
01-0107-002-02	Neebing River	02AB008	187	0.54×10^5
01-0108-001-02	Kaministiquia R. at Kakabeka Falls*	02AB010	6710	1.67×10^6
19-0001-005-02	Wabigoon R. at Dryden	05QD016	2300	0.48×10^6
19-0001-036-02	Wabigoon R. at Quibell	05QD006	6270	1.38×10^6
19-0001-015-02	Chukuni River near Ear Falls**	05QC001	4920	0.922×10^6
19-0001-004-02	Rainy River	05PC019	38600	8.73×10^6
19-0001-002-02	Winnipeg River Kenora Powerhouse	O5PE006	70400	3.01×10^6 (one branch only)

* upstream of station
** downstream of station

Appendix 1.4 History of Changes and Revisions in Analytical Methods *(from OMOE 1990 Methods Manual, Thunder Bay Laboratory)*

1. Acidity (ACDT)

1.1 June 1986.

1.1.1 The method was changed from analysis using a pH meter to the phenolphthalein indicator method. The pH meter is still used for highly-coloured samples where the end-point is not easily distinguished.

2. Ammonia total filtered reactive (NNHTFR); Nitrite filtered reactive (NNO_2FR); Nitrate filtered reactive (NNO_3FR); Soluble Phosphate (PPO_4FR)

2.1 1978.

2.1.1 Technicon AAII equipment was placed on-line. Conversion from a cadmium reduction to a hydrazine reduction for nitrite and nitrate was introduced.

2.2 1983.

2.2.1 Ammonia.

Phenol no longer dissolved. The crystals are now weighed out. The method changed from an acetone catalyst to a nitroprusside catalyst.

2.2.2 Nitrite.

The Brig-35 is no longer added to the Working Buffer.

2.2.3 Nitrite and Nitrate.

Ambelite resin was changed from IR 120H to IR 120Na and stored in saturated NaCl rather than a 10% Hydrochloric Acid Solution. The length of the column was shortened from 8 cm to 4 cm, and was prepared fresh daily. All NO_3 lines are cleaned with 10% Hydrochloric Acid Solution (except sample line).

2.2.4 Phosphorus.

The method was changed from a stannous reduction to an ascorbic acid reduction and a formation of phosphoantimonyl-molybdate complex.

2.3 1984.

2.3.1 All Channels.

The Intermediate Standards are prepared fresh weekly. The Working Standards are prepared fresh daily.

2.3.2 Phosphorus.

The range changed from 0.08 mg/l to 0.10 mg/l.

2.4 1986.

2.4.1 All Channels.

The samples are no longer filtered unless necessary.

2.5 1988.

All channels went on microcomputer control using a Hewlett Packard computer and Direct Computer Input (DCI) software.

3. Arsenic (ASUT)

3.1 October, 1986.

The sulphuric acid trap was added to the hydride gas stream to reduce the amount of water vapour entering the tube furnace and to increase sensitivity.

3.2 January, 1989.

The Cathodeon hollow cathode lamp for arsenic was replaced with a Hamamatsu lamp due to stability problems with the former. Lamp current was lowered from 9 mA to 4 mA according to the manufacturer's specifications.

4. Biological Oxygen Demand (BOD_5)

4.1 Prior to May 1981.

Samples requesting BOD_5 analysis were sent to the Toronto Rexdale Laboratory.

4.2 May 1981.

Modified procedures for BOD_5 tests were initiated.

5. **Chloride, Unfiltered Reactive (CLIDUR)**

5.1 Prior to 1977.

Chlorides were analyzed using an argentometric method where silver chloride was quantitatively precipitated by the addition of a standard solution of silver nitrate in the presence of a potassium chromate indicator.

5.2 1977.

The method was updated to a Fisher Titralyzer II System using a KCl ion-specific electrode and titrating with standard silver nitrate.

5.3 January 1, 1980.

The automated colourimetric Technicon AAII method was put on-line and is presently being used.

6. **Coliform, Fecal (FCMF); Coliform, total (TCMF)** (based on conversation with Alice Chony, OMOE Lab, Thunder Bay)

6.1 1970.

Analyses moved to Thunder Bay

6.2 1987.

In recent years, the interpretation of fecal coliform data has changed. High fecal coliform values in pulp and paper effluents were recognized as potentially including false positives due to the presence of Klebsiella pneumoniae a common, naturally occurring bacterium in wood wastes. Analyses for E. coli, which confirms human and/or animal waste as a source, were added to aid in interpreting these data.

7. **Colour, True (COLTR)**

7.1 Colour was analyzed by the Klett-Summerson photoelectric colourimeter and reported as apparent colour.

7.2 November 1984 to August 1985.

Comparisons between the Klett-Summerson photoelectric colourimeter and the automated method were done.

7.3 August 1985.

Method was changed to the automated true colour method.

8. Conductivity; Alkalinity, total; and pH (COND25, ALKT and pH)

8.1 1981.

An automated system which simultaneously determined pH, conductivity and alkalinity using Fisher equipment was introduced.

8.2 1986.

The Fisher automated titration system was replaced in 1986/87 with Radiometer equipment consisting of a CDM83 Conductivity Meter, TTT85 Titrator, ABU 80 Auto-Burette, PRS12 Alpha Printer and SAC 80 Sample Changer.

9. Iron (FEUT)

9.1 No changes.

10. Hardness, total (HARDT)

10.1 1986.

The hardness test performed at the Thunder Bay Laboratory incorporated the use of an Auto-Burette.

11. Mercury (HGUT)

11.1 Prior to 1969.

Mercury analysis was rarely done. The detection limit of the colourimetric method used was too high for "clean" water analysis.

11.2 January 1980.

The preservative used for samples was changed from $KMnO_4$ to $K_2Cr_2O_7$.

11.3 February 1989.

New Mercury Standards introduced G.T. Baker 'Dilut-It', $Hg(NO_3)_2$, 100 mg/L, replacing the 500 mg/L methyl Mercuric Chloride Standard (CH_3HgCl).

11.4 March 1989.

The Reducing Solution was changed from stannous sulphate to stannous chloride. The Stannous Chloride Solution was found to be stable for a period of one week and does not require filtration.

Appendix 1.4 Cont'd ...

11.5 April 1989.

New QCA and QCB Controls were made using the 100 mg/L Mercuric Nitrate Standard.

NOTE: The above refers to routine mercury analyses, not the low level analyses that are carried out only on designated samples.

12. **Metals: Aluminum (ALUT); Cadmium (CDUT); Cobalt (COUT); Copper (CUUT); Chromium (CRUT); Iron (FEUT); Manganese (MNUT); Molybdenun (MOUT); Nickel (NIUT); Lead (PBUT); Silver (AGUT); Zinc (ZNUT).**

12.1 Early 1970's

Analyses were moved from the Toronto lab to Thunder Bay. (J. Thomas, OMOE Lab, Toronto, pers. comm.)

12.2 May 1988.

AAS was replaced as the method of analysis by ICP-AES. This has allowed the simultaneous measurement of all 18 elements and greater sample throughput.

13. **Sulphate, unfiltered reactive (SSO_4UR)**

13.1 Prior to 1985.

Sulphate was analyzed using the $BaCl_2$-methylthymol blue colourimetric method.

13.2 1985.

Analysis was changed from colourimetry to ion chromatography using the Wescan Model ICM.

14. **Turbidity (TURB)**

14.1 Turbidity was analyzed using the Hach 2100A instrumentation.

14.2 March 1987.

Turbidimeter measurements using the Hach Model 18900 were initiated.

15. **Silicates (SIO_3UR)**

15.1 Prior to January 1977.

Samples for silica analysis were sent to the Toronto Regional Laboratory.

Appendix 1.4 Cont'd ...

15.2 Since January 1977.

Silica and sulphate were analyzed together on an AAI system with an operating range of 0 to 4.0 mg/L Si.

15.3 January 1978.

The silica Auto-Analyzer method was updated from the MOE AAI system to the Technicon AAII system. The changed was necessary because of sensitivity changes during the operation of the MOE method.

16. **Total Kjeldahl nitrogen, unfiltered reactive (NNTKUR); Total unfiltered phosphorus (PPUT)**

16.1 January 1981.

The flask digestion procedure was changed to the hot block method currently used.

16.2 February 1989.

Direct Computer Input (DCI) was incorporated in this method.

17. **Solids, Particulate (RSP)**

17.1 September 1984.

The Commodore computer was set up and used to provide computerized calculations.

17.2 September 1988.

DCI with Commodore computer.

17.3 June 1989.

The DCI was complemented with an in-house Lotus program.

18. **Solids, Total (RST)**

18.1 September 1984.

The Commodore computer was set up and used to provide oeprator computerized input.

18.2 September 1988.

DCI with the Commodore computer.

18.3 April 1989.

The Mopet was proved and its usage was started.

18.4 June 1989.

The DCI was complemented with an in-house Lotus program (see Reference 1.7.4).

Appendix 1.5 Summary of detection limits of analytical methods.

Parameter	Code	Minimum Measurable Amount (W) (mg/ℓ unless specified)	Date
Acidity	ACDT	N/A	
Alkalinity	ALKT	N/A	automated 1981
Aluminum	ALUT	0.005**	since 1986
Arsenic	ASUT	0.01**	until May 1978
		0.004**	until Feb. 1979
		0.001**	from July 1979
Biochemical Oxygen Demand	BOD_5	0.1*	since 1985
Cadmium	CDUT	0.002**	until May 1977
		0.001**	until Jan. 1982
		0.0005**	until Jan. 1988
		0.0002**	from Jan. 1988
Chloride	CLIDUR	0.5*	1977 - 1980
		0.05*	since July 1980
Chromium	CRUT	variable**	from 1973
		0.02**	from Feb. 1977
		0.001**	from Apr. 1979
		0.002**	from July 1982
		0.001**	from Jan. 1988

* based on QC summaries done since August, 1978 (Thunder Bay Laboratory OMOE)

Appendix 1.5 Cont'd ...

Parameter	Code	Minimum Measurable Amount (W) (mg/ℓ unless specified)	Date
Cobalt	COUT	0.001** 0.002** 0.001**	in Dec. 1978 in May 1986 in 1989
Coliforms - Total	TCMF	N/A***	
Coliforms - Fecal	FCMF	N/A***	
Colour	COLTR	approx. 1.0* 2.0* 0.5* (TCU)	1978 - 1982 1982 - 1985 since Aug. 1985
Conductivity (at 25°C)	COND25	1.0* (umhos/cm)	
Copper	CUUT	0.01** 0.001** 0.0005**	from 1973 from May 1978-1988 from Jan. 1988
Cyanide - Total	CCNAUR	N/A	
Hardness	HARDT	0.5*	since 1978
Iron	FEUT	.005***	since 1976

* based on QC summaries done since August, 1978 (Thunder Bay Laboratory OMOE)
** based on W values listed on SIS reports for the Nipigon River station (01-0090-002-02)
*** influenced by background conditions.

Appendix 1.5 Summary of detection limits of analytical methods.

Parameter	Code	Minimum Measurable Amount (W) (mg/ℓ unless specified)	Date
Acidity	ACDT	N/A	
Alkalinity	ALKT	N/A	automated 1981
Aluminum	ALUT	0.005**	since 1986
Arsenic	ASUT	0.01**	until May 1978
		0.004**	until Feb. 1979
		0.001**	from July 1979
Biochemical Oxygen Demand	BOD_5	0.1*	since 1985
Cadmium	CDUT	0.002**	until May 1977
		0.001**	until Jan. 1982
		0.0005**	until Jan. 1988
		0.0002**	from Jan. 1988
Chloride	CLIDUR	0.5*	1977 - 1980
		0.05*	since July 1980
Chromium	CRUT	variable**	from 1973
		0.02**	from Feb. 1977
		0.001**	from Apr. 1979
		0.002**	from July 1982
		0.001**	from Jan. 1988

* based on QC summaries done since August, 1978 (Thunder Bay Laboratory OMOE)

Appendix 1.5 Cont'd ...

Parameter	Code	Minimum Measurable Amount (W) (mg/ℓ unless specified)	Date
Cobalt	COUT	0.001** 0.002** 0.001**	in Dec. 1978 in May 1986 in 1989
Coliforms - Total	TCMF	N/A***	
Coliforms - Fecal	FCMF	N/A***	
Colour	COLTR	approx. 1.0* 2.0* 0.5* (TCU)	1978 - 1982 1982 - 1985 since Aug. 1985
Conductivity (at 25°C)	COND25	1.0* (umhos/cm)	
Copper	CUUT	0.01** 0.001** 0.0005**	from 1973 from May 1978-1988 from Jan. 1988
Cyanide - Total	CCNAUR	N/A	
Hardness	HARDT	0.5*	since 1978
Iron	FEUT	.005***	since 1976

* based on QC summaries done since August, 1978 (Thunder Bay Laboratory OMOE)
** based on W values listed on SIS reports for the Nipigon River station (01-0090-002-02)
*** influenced by background conditions.

Appendix 1.5 Cont'd ...

Parameter	Code	Minimum Measurable Amount (W) (mg/ℓ unless specified)	Date
Lead	PBUT	0.01**	from 1973
		0.001**	from Aug. 1979
		0.003**	from Apr. 1982
		0.002**	from Jan. 1988
Manganese	MNUT	0.02 (variable)**	from 1973
		0.001**	from 1978
Mercury - routine	HGUT	0.05**	until 1973
		0.03**	from July 1985
		0.01**	from Jan. 1989
Mercury - low level	HGUT	0.005**	from Jan. 1983
Molybdenum	MOUT	.0005**	since 1986
Nickel	NIUT	0.01**	from 1973
		variable	from 1977
		0.001**	from May 1979
Nitrogen - Ammonia	NNHTFR	.01*	since 1978
Nitrogen - Nitrate	NNO3FR	.01*	since 1978
Nitrogen - Total Kjeldahl	NNTKUR	.01*	since 1978
Oxygen - Dissolved	DO	unknown	field data

* based on QC summaries done since August, 1978 (Thunder Bay Laboratory OMOE)
** based on W values listed on SIS reports for the Nipigon River station (01-0090-002-02)
*** influenced by background conditions.

Appendix 1.5 Cont'd ...

Parameter	Code	Minimum Measurable Amount (W) (mg/ℓ unless specified)	Date
pH	pH	unknown	field data
Phosphorus - Total	PPUT	.001*	since 1978
Pseudomonas (counts/100 ml)	PSAMF	N/A	
Phosphorus - Phosphate	PPO4FR	.001*	since 1978
Silicates	SIO3UR	.02*	since 1978
Sodium	NAUR	.05*	since 1978
Solids - Particulate	RSP	1.0*	since 1978
Solids - Total	RST	5.0*	since 1978
Sulphate	SSO4UR	.1*	since 1978
Turbidity	TURB	.05*	since 1978
Zinc	ZNUT	0.001**	from 1973
		variable	from Apr. 1976
		0.001**	from Mar. 1979

* based on QC summaries done since August, 1978 (Thunder Bay Laboratory OMOE)
** based on W values listed on SIS reports for the Nipigon River station (01-0090-002-02)
*** influenced by background conditions.

APPENDIX 1.6 TEST GROUP CODES WITH DESCRIPTIONS AND TEST NAMES

(from OMOE 1990b)

CODE DESCRIPTION/TEST NAMES							TEST GROUP
TBWQM2	T.BAY WQM 2 MICRO + CHEM						
TCMF	ECIGMF	BOD_5	RST	RSP	PPUT	PPO4FR	HARDT
ALKT	CLIDUR	PH	COLTR	TURB	COND25		
TBWQM3	T.BAY WQM 3 MICRO + CHEM						
BOD_5	RST	RSP	PPUT	PPO4FR	NNHTFR	NNTKUR	NNO2FR
NNOTFR	HARDT	ALKT	CLIDUR	PH	COLTR	TURB	COND25
TCMF	ECMPN						
TBWQM4	T.BAY WQM 4 MICRO + CHEM						
BOD_5	RST	RSP	PPUT	PPO4FR	NNHTFR	HARDT	ALKT
ACDT	CLIDUR	PH	COLTR	TURB	COND25	TCMF	ECMPN
TBWQM5	T.BAY WQM 5 MICRO + CHEM						
FCMF	BOD_5	RST	RSP	SSO4UR	PPUT	PPO4FR	NNHTFR
NNTKUR	NNO2FR	NNOTFR	HARDT	ALKT	ACDT	CLIDUR	PH
COLTR	TURB	COND25	SIO3UR				
TBWQM6	T.BAY WQM 6 MICRO + CHEM						
FCMF	FSMF	BOD_5	RST	RSP	RSF	PPUT	PPO4FR
NNTKUR	NNO2FR	NNOTFR	ALKT	COLTR	TURB		
TBWQM7	T.BAY WQM 7 CHEM ONLY						
RST	RSP	RSF	PPUT	PPO4FR	ALKT	PH	COND25
SIO3UR							
TBWQM8	T.BAY WQM 8 MICRO + CHEM						
TCMF	PSAMF	ECMPN	BOD_5	RST	RSP	SSO4UR	PPUT
PPO4FR	NNHTFR	NNTKUR	NNO2FR	NNOTFR	HARDT	ALKT	ACDT
CLIDUR	PH	COLTR	TURB	COND25			

Appendix 1.6 Cont'd ...

CODE DESCRIPTION/TEST NAMES						TEST	GROUP
TBWQM9	T.BAY WQM 9 MICRO + CHEM						
TCMF	ECMPN	BOD_5	RST	RSP	NAUR	PPUT	PP04FR
NNHTFR	NNTKUR	NNO2FR	NNOTFR	HARDT	ALKT	ACDT	CLIDUR
PH	COLTR	TURB	COND25				
TBWQ10	T.BAY WQM 10 MICRO + CHEM						
FCMF	PSAMF	BOD_5	RST	RSP	PPUT	PP04FR	NNHTFR
NNTKUR	NNO2FR	NNOTFR	HARDT	ALKT	CLIDUR	PH	COLTR
TURB	COND25						
TBCR1	T.BAY W.Q.M.A.						
NAUR	KKUR	CAUR	MGUR	SS04UR	SIO3UR		
TBCR2	T.BAY W.Q.M.B.						
BOD_5	RST	RSP	RSF	NNHTFR	NNO2FR	NNOTFR	PPUT
PP04FR	HARDT	ALKT	CLIDUR	COND25	PH	COLTR	TURB
TBCR3	T.BAY W.Q.M.C.						
COND25	PPUT	PPO4FR	RSP	ALKT	NNOTFR	PH	NNO2FR
TBCR4	T.BAY BACKGROUND SURV.						
BOD_5	RST	RSP	RSF	COD	NNHTFR	NNTKUR	NNO2FR
NNOTFR	PPUT	PP04FR	HARDT	ALKT	ACDT	CLIDUR	PH
COLTR	TURB	COND25	NAUR	KKUR	CAUR	MGUR	SSO4UR
SIO3UR	CDUT	COUT	CUUT	ZNUT	PBUT	NIUT	FEUT
MNUT	CRUT	ALUT	MOUT	ASUT	HGUT		
TBCM3	T.BAY METALS C						
CUUT	PBUT	CDUT	HGUT				
TBCM4	T.BAY METALS 4						
CDUT	COUT	CUUT	ZNUT	PBUT	NIUT	FEUT	MNUT

Appendix 1.6 Cont'd ...

CODE DESCRIPTION/TEST NAMES									TEST GROUP
TBCM5	T.BAY METALS 5								
CUUT	ZNUT	NIUT	FEUT	MNUT					
TBCM6	T.BAY METALS 6								
CDUT	COUT	CUUT	ZNUT	PBUT	NIUT	FEUT	MNUT	HGUT	ASUT
TBCM7	T.BAY METALS 7								
CDUT	COUT	CUUT	ZNUT	PBUT	NIUT	FEUT	MNUT	CRUT	HGUT
TBCM8	T.BAY METALS 8								
CDUT	CUUT	ZNUT	PBUT	CRUT	HGUT	ASUT			
TBCM9	T.BAY METALS 9								
CUUT	ZNUT	PBUT	CRUT	HGUT	ASUT				
T.BAY CHLORPHENOLS									

APPENDIX 2. 1.

A SAS/GRAPH* PROGRAM TO PRODUCE BOX-WHISKER DIAGRAMS FROM ENVIRONMENTAL DATA

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Abstract

Program code and documentation are provided for a SAS/GRAPH program that extracts order statistics from an environmental data set, graphs the results in the form of a box-whisker diagram. Order statistics used in this program include sample minimum, 25th percentile, median (50th percentile), 75th percentile and sample maximum. This type of data summary and presentation is well suited to exploratory analysis of central tendency and trend in larger data sets.

Introduction

Summary and graphical presentation should generally be a first step in understanding and analysing environmental data sets, which are often large and have skewed, non-normal distributions. An important feature of preliminary or diagnostic data analysis is that data should be allowed to 'speak for themselves', without being subjected to strong distributional assumptions. In many cases, useful inferences about central tendency and trend can be derived from this type of preliminary analysis. With less obvious cases, graphical analysis can guide the selection of the appropriate formal statistical procedure.

Here a method and rationale are presented for the use of 'boxplot' summaries of environmental data. Computer program code is provided for the SAS programming language, but the programming approach is easily adaptable to other statistical analysis systems that do not contain boxplot routines.

Order Statistics and Quantiles

Order statistics are derived from a rank-ordered data set. Whereas nonparametric ranking procedures concern the properties of the ranks, order statistics concern the quantitative values associated with the ranks.

Thus the order statistics are also *quantiles*, i.e. the values associated with given cumulative fractions or percentages of the data distribution such as quartiles, deciles or percentiles. Herein a quantile Q_t indicates that the associated numerical value exceeds $t\%$ of the observations. For example, Q_{50} denotes the median which is greater than 50% of the sample data.

Sample estimates of particular quantiles may be derived indirectly from the empirical cumulative distribution function as estimated with a 'plotting position' formula. The most commonly employed plotting position formulae take the general form:

$$\widehat{P}_i = \frac{i - \alpha}{n + 1 - 2\alpha} \qquad i = 1, \ldots, n \tag{1}$$

where i are the ranks of the n sample data arranged in ascending order, i.e. $X_1 \leq X_2 \leq \cdots \leq X_i \leq \cdots \leq X_n$ and $\widehat{P}_i$ is a sample estimate of the cumulative distribution function of the ith order statistic X_i. If $\widehat{P}_i = t/100$, then X_i is the sample estimate of Q_t. For $\widehat{P}_i < t/100 < \widehat{P}_{i+1}$, Q_t may be estimated by linear interpolation. Perhaps the two most widely used plotting position formulae are Weibull's ($\alpha = 0$) and Hazen's ($\alpha = .5$). The latter is the choice of Chambers et al. (1983) and Cleveland (1985), while Cunnane (1978) discusses these and several alternatives.

In general, the central order statistics, e.g. the three quartiles, are robust statistics as other members of the data set influence order statistics only through their relative ordering, not their magnitudes. For medium to large sample sizes, e.g. $n \geq 20$, central quantile estimates are negligibly influenced by the choice of plotting position.

Tukey Five Number Summary

The five number summary invented by Tukey (1977) in the context of exploratory data analysis is a highly effective means of summarizing data. The five numbers are:

1. Sample maximum
2. Q_{75}, 75th percentile or 3rd quartile
3. Q_{50}, 50th percentile, 2nd quartile or median
4. Q_{25}, 25th percentile or 1st quartile
5. Sample minimum

The two extrema are obtained directly from sample data, while the quartiles must be estimated via the preferred plotting postion formula. This list should be extended to include a sixth number, n, the number of observations from which these statistics are derived. Sample size is an important consideration which should always be reported with the five order statistics listed above. Unlike the arithmetic mean or even in certain cases the geometric mean, the median is a robust location measure that is relatively insensitive to distribution shape and the presence of outliers.

The Box-whisker Diagram, or Boxplot

Reckhow and Chapra (1983) and Mcleod et al. (1983) introduced boxplots (Figure 1) to the water resources field, and this method has become a widely popular data summarization format in technical journals and reports. Graphical presentation of the five number summary in the form of boxplots greatly enhances tabular presentations of data. Location, scale, skew, extrema, and trend can be readily grasped at a glance (Figure 2).

Numerous variants of the boxplot format can be adopted. For example, for large sample sizes, e.g. $n \geq 30$, quantiles Q_{90} and Q_{10} might be substituted for the quartiles Q_{75} and Q_{25}, to produce a box bounding the central 80% of the data that more closely approximates the confidence bands commonly applied in more formal contexts. Other variants have appeared in the literature. To summarize total phosphorus data, Reckhow and Chapra (1983) used the notched boxplot of McGill et al. (1978) on which a notch approximates the 95% confidence bands about the sample median. They also varied the width of the boxplot to indicate relative sample size. Tukey (1977) and Cleveland (1985) present further alternatives on which potential outliers and extreme values respectively are plotted as distinct points. These and other flourishes may be developed as desired. As a general diagnostic tool, the standard boxplot of Figure 1 is adequate for routine summary of environmental data.

BOXANNO.SAS

This program, listed with documentation in Appendix 1, uses BASE/SAS and SAS/GRAPH to produce box-whisker diagrams from a SAS data set. Option PCTLDEF=4 of PROC UNIVARIATE invokes the Weibull plotting position which is the only choice embraced by the general formula (1). Again, employing the alternatives should produce no graphically perceptible differences for data sets of modest size. Each data record should generally comprise station and date variables followed by one or more environmental measurements (Table 1). Users of this program should be relatively familiar with the SAS programming language, and be able to create a SAS data set, and enter, edit and submit SAS program files. Details of these procedures will vary somewhat depending on the type of computer being used. The BOXANNO.SAS program is modular, and can be easily expanded to produce boxplots for more than one variable. Experienced users will find it easy to transform variables, to produce mulit-colored plots, or to modify title size and position, axis, format, labelling, etc. Figure 2 was produced on a Postscript laser printer with PC-SAS version 6.3.

References

CHAMBERS, J.M., W.S. CLEVELAND, B. KLEINER, and P.A. TUKEY. 1983. Graphical methods for data analysis. Duxbury, Boston, MA. 395p.

CLEVELAND, W.S. 1985. The elements of graphing data. Wadsworth, Monterey, CA. 323p.

CUNNANE, C. 1978. Unbiased plotting positions–a review, J. Hydrol. 37:205-222.

McGILL, R., J.W. TUKEY, and W.A. LARSEN. 1978. Variations of boxplots. The American Statistician 32:12-16.

McLEOD, A.I., K.W. HIPEL, and F. CAMACHO. 1983. Trend assessment of water quality time series. Water Resour. Bull. 19(4):537-547.

RECKHOW, K.H., and S.C. CHAPRA. 1983. Engineering approaches for lake management, Vol. 1: data analysis and empirical modeling. Butterworth, Boston, MA. 340p.

SAS. 1985a. SAS User's Guide: Basics, Version 5 Edition. SAS Institute Inc., Cary, NC. 1290p.

SAS. 1985b. SAS/GRAPH User's Guide: Basics, Version 5 Edition. SAS Institute Inc., Cary, NC. 596p.

TUKEY, J.W. 1977. Exploratory data analysis. Addison-Wesley, Reading, MA. 688p.

Table 1. Example of data format for BOXANNO.SAS.

Station i.d.	Date	Conductivity	Total phosphorus	pH	etc.
14	860708	180	0.021	7.3	
14	860810	177	0.028	7.1	
21	860708	80	0.009	6.9	
21	860810	83	0.012	6.7	
etc.					

Figure 1. BOXPLOT elements.

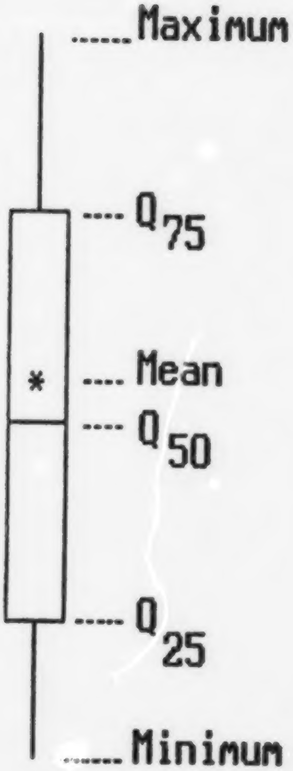
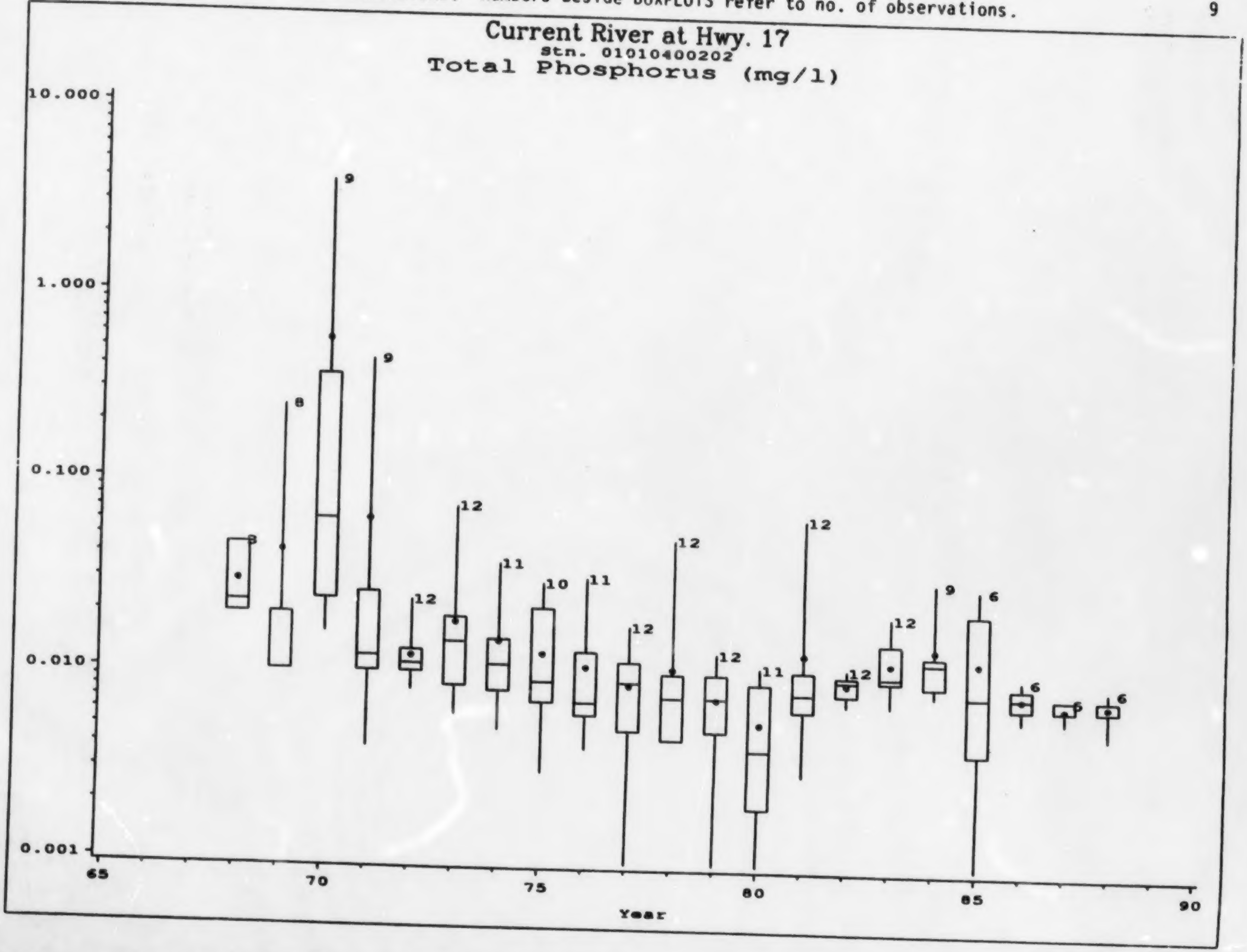

Maximum
Q_{75}
Mean
Q_{50}
Q_{25}
Minimum

Figure 2. Sample output from BOXANNO.SAS. Numbers beside BOXPLOTS refer to no. of observations.



Appendix 1. Generic program listing for BOXANNO.SAS. Words or phrases enclosed within square brackets denote user-supplied variable names. The square brackets should not be used in the SAS program.

```
/* tell SAS where your data file is */
        LIBNAME  [SAS libname]  '[directory path]' ;
        DATA TEMP; SET [SAS libname].[data file name]

/* select station number */
        IF STN = [your station number] THEN OUTPUT ;

/* select time variable and environmental variable(s) to be graphed */
        KEEP [time variable] [var1] [var2] ... [var_n] ;

/* optional line to eliminate outliers, so that more resolution
   in the Y-axis is available /*
        IF [var] > [upper limit] THEN [var] = . ;

/* optional line to transform a variable, i.e. to log_10 */

        [new var] = LOG10([var]);
```

NOTE: the following portion of the program may be repeated to produce boxplots for more than one variable.

```
/* begin "UNIVARIATE" procedure to calculate boxplot statistics */

        PROC UNIVARIATE NOPRINT DATA=TEMP ;

   /* specify first environmental variable */

                VAR [var1]; BY [time variable] ;

      /* direct "UNIVARIATE" output to temporary file UNIOUT1,
     and assign variable names to boxplot statistics */

                OUTPUT OUT=UNIOUT1
                N=N NMISS=NMISS MEAN=MEAN MIN=MIN MAX=MAX Q1=Q25
                MEDIAN=MEDIAN
                Q3=Q75 ;

                RUN ;

/* create SASGRAPH "annotate" dataset, which draws boxplots for each
   time interval, according to the output from the UNIVARIATE procedure */

                DATA BOXANNO;LENGTH FUNCTION $8 COLOR $8 TEXT $8 ;
                SET UNIOUT1 ;
                KEEP FUNCTION X Y TEXT XSYS YSYS COLOR N ;
                XSYS='2'; YSYS='2'; COLOR='BLUE'; OUTPUT ;
```

```
  /* if there are no observations for current time interval, branch
to label "OK".

          IF N=0 THEN GO TO OK ;

  /* draw box */

          FUNCTION='MOVE'; X= [time variable] -.25; Y=Q25; OUTPUT ;
          FUNCTION='DRAW'; X= [time variable] +.25; Y=Q25; OUTPUT ;
          FUNCTION='DRAW'; X= [time variable] +.25; Y=Q75; OUTPUT ;
          FUNCTION='DRAW'; X= [time variable] -.25; Y=Q75; OUTPUT ;
          FUNCTION='DRAW'; X= [time variable] -.25; Y=Q25; OUTPUT ;

  /* draw median bar */

          FUNCTION='MOVE'; X= [time variable] -.25; Y=MEDIAN; OUTPUT ;
          FUNCTION='DRAW'; X= [time variable] +.25; Y=MEDIAN; OUTPUT ;
  /* draw "maximum" whisker */

          FUNCTION='MOVE'; X= [time variable] Y=Q75; OUTPUT ;
          FUNCTION='DRAW'; X= [ Y=MAX; OUTPUT ;

  /* draw "minimum" whisker */

          FUNCTION='MOVE'; X= [ Y=Q25; OUTPUT ;
          FUNCTION='DRAW'; X= [ Y=MIN; OUTPUT ;

  /* draw asterisk at mean */

          FUNCTION='SYMBOL'; X= [ Y=MEAN; COLOR='GREEN'; TEXT=':'; OUTPUT;

  /* if no observations, indicate "0"; otherwise indicate number of
observations */

          OK: FUNCTION ='LABEL'; X= [time variable] +.3; IF N=0 THEN Y=0;
          ELSE Y=MAX;
          TEXT=LEFT(PUT(N,F2.0)); OUTPUT;

  /* this symbol assignment plots "blanks" on graph axes generated
by the GPLOT procedure; the boxplots are then drawn on the blank
plot, by the "PLOT" statement below */

          SYMBOL1 V=NONE;

  /* GPLOT "GOPTIONS" for your printer or plotter*/

          GOPTIONS DEVICE=PSL ROTATE=LANDSCAPE GACCESS='SASGASTD>LPT1:'
          BORDER;

  /* specify title and subtitles for graph; "J" specifies text justification,
"H" specifies text size */

          TITLE1 J=C H=2 '[text string]';
          TITLE2 J=C H=1.5 '[text string]';
          TITLE3 J=C H=1.5 '[text string]';
```

```
/* specify formats for horizontal and vertical axes*/

        AXIS1 LABEL= (' ') LOGBASE=10 LOGSTYLE=EXPAND
        ORDER=(0.001 0.01 0.10 1.0 10.0);

        AXIS2 LABEL= ('Year') ORDER=(65 TO 90 BY 5)


  /* start GPLOT procedure; produce blank scatterplot (to generate
axes); then overlay with boxplots */


        PROC GPLOT DATA=TEMP ANNO=BOXANNO;
        PLOT [var1] * [time variable] =1 /

        /* identify format statements for horizontal and vertical axes*/

        HAXIS = AXIS1
        VAXIS = AXIS2;

        RUN;
```

Appendix 2.2 Extreme values that have been excluded from the figures

Location Code (to interpret code see Appendix 1.4)	Parameter Year - Approximate Value
North Shore	
01-0057-001-02	Cond 77-900 CL 77-230 pH 88-0 RSP 79-250 PP 78-0.5 Zn 76-0.1 As 74-0.02 Cu 89-0.044 Cr 79-0.02
01-0060-001-02	pH 88-0 PP 88-4.4 Cr 84-0.22 Cu 84-0.15 Hg 74-0.5
01-0060-002-02	pH 88-0 Cr 89-0.22
01-0060-003-02	pH 88-0 pH 78-4 Cr 79-0.16 Cr 81-0.145 Ni 81-0.051
01-0060-004-02	pH 88-0 Cu 76-0.085
01-0060-005-02	pH 88-0 Cr 79-0.1 Ni 76>4.
01-0060-006-02	pH 88-0 Cr 79-0.075 Zn 77-0.19
01-0060-007-02	pH 88-0
01-0060-008-02	pH 88-0
01-0060-010-02	Cond 89-1800
01-0067-001-02	pH 88-0 Zn 88-56
01-0090-002-02	Alkt 88-0
01-0092-001-02	pH 89-2 Cond 82>1000 Cond 89-5600 PPUT 76-27
Thunder Bay	
01-0104-001-02	PP 70-6
01-0104-002-02	PP 70-4 RSP 89>60
01-0105-001-02	pH 78-2 RST 70>3000 RSP 70-2500 FCNF 81-3800
01-0106-001-02	PP 71-150 Ca 79>0.009 Cu 81>0.01
01-0106-002-02	Cond 76-600 pH 76-2 Cu 79>0.42
01-0107-001-02	PP 70-600 RSP 68-1200 RSP 71-600 FCNF 72-1600
01-0107-002-02	NTK 70-4.5 NTK 72>4.0
01-0109-001-02	PP 88-1.8 Ca 79>0.019
01-0109-002-02	PP 69-1.9 Ca 79>0.019 Mn 83>0.9
01-0110-001-02	Ca 79>0.019 Mn 83>0.9
Kaministiquia R.	
01-0108-001-02	DO 75-65
01-0108-002-02	PP 70-1 Ca 79>0.019 Mn 80>0.5 Zn 7-0.18 TCNF 77-3.5 xx 10^5
01-0108-003-02	TCNF 82-2.5 x 10^5
01-0108-004-02	Cu 79>0.8
01-0108-005-02	RSP 72-200 PP 70-0.8 Ni 77-0.06

Appendix 2.2 Cont'd ...

Location Code
Parameter Year - Approximate Value

(to interpret code see Appendix 1.4)

Wabigoon River

19-0001-005-02	Cond 77-700 PP 80-2.1 Mn 86-0.95
19-0001-006-02	TCMF 80-900x10^6 TCMF 81-300x10^6

Rainy River

19-0001-004-02	PP 89-42 NTK 68-5.3 Cu 72-74 17 values between 0.2 and 1.4 Ni 73-0.52 Ni 68-P 74,12 values between 0.04 and 0.53 Zn 68-74; 16 values between 0.04-0.32 TCMF 72-380,000 TCMF 73- 8 x 10^5
19-0001-012-02	PP 69-0.8 TCMF 73-2x10^6 FCMF 77=1.5x10^6
19-0001-003-02	BOD 78-18 PP 79-1.3
19-0001-010-02	CL 79-60 Cond 79-350 PP 69-0.5
19-0001-009-02	PP 69-0.7

Winnipeg River

19-0001-001-02	Cond 88-500 RST 70>420 PP 70-0.3 Cu 84-0.07 Zn 70-0.28 Zn 71-0.6 FCMF 73-7x10^6
19-0001-002-02	Cond 88-570 FCMF 73=8x10^5 FCMF 77=1.6x10^6, 2.1x10^6, 2.3x10^6, 3.8x10^6, 4.1x10^6

Red Lake Area

19-0001-008-02	CL 71-32 Cu 70,71-16-20; Zn 71-0.65
19-0001-016-02	RSP> 5000 As 88-750 Cu 81>8 Hg 72-60 Mn 74>5.3 FCMF 73,74>3000
19-0001-032-02	Hg 72-60 Cu 81-5.8 FCMF 81-5000
19-0001-015-02	Cond 76-1200 RST 76-1070 Cu 81>0.41 Fe 80-4.5 Hg 72-60 Ni 81-0.6 FCMF 73,74>3000
19-0001-033-01	Hg 72-40,180

APPENDIX 3.1 Median values for PWQMN Stations in the Lake Superior Drainage Basin

LOCATION:	Flow** (m^3/s)	BOD$_5$ mg/ℓ	RST mg/ℓ	RSP mg/ℓ	PPUT mg/ℓ	PPO$_4$FR mg/ℓ	HARDT mg/ℓ	ALKT mg/ℓ	CLIDUR mg/ℓ	pH	COLTR TCU	TURB FTU	COND25 uhmos/cm	NNHTFR mg/ℓ
North Shore														
White River 01-0057-001-02	-	1.2 (71)	100 (87)	1 (197)	0.009 (195)	0.001 (196)	62 (2)	65 (166)	1.0 (71)	7.6 (199)	38 (1)	1.0 (69)	146 (182)	0.03 (71)
Heyward Creek 01-0057-002-02*	-	-	780 (35)	1 (35)	0.010 (35)	< (33)	345 (33)	21 (35)	46.0 (33)	7.0 (35)	30 (35)	0.6 (35)	1001 (35)	3.90 (35)
Pic River 01-0060-001-02	64.6 (404)	1.0 (131)	180 (83)	60 (603)	0.045 (600)	0.009 (551)	86 (2)	98 (474)	1.0 (73)	8.0 (428)	58 (58)	17.5 (144)	184 (546)	0.04 (72)
Black, Hwy. 17 01-0060-002-02	37.1 (399)	1.0 (125)	160 (81)	15 (595)	0.018 (592)	0.003 (545)	94 (1)	78 (471)	1.0 (67)	7.9 (421)	54 (54)	4.8 (138)	182 (541)	0.04 (67)
Black, Hwy. 614 01-0060-003-02	-	0.8 (137)	170 (135)	5 (136)	0.010 (134)	0.001 (139)	121 (145)	100 (138)	1.2 (136)	7.8 (156)	50 (51)	1.6 (138)	234 (143)	0.06 (144)
Black, D/S Nose 01-0060-004-02*	-	1.0 (136)	200 (134)	2 (135)	0.011 (135)	0.001 (137)	125 (144)	67 (136)	2.3 (133)	7.5 (155)	58 (48)	1.8 (137)	262 (142)	0.62 (142)
Fox, D/S Lake 01-0060-005-02*	-	0.6 (138)	190 (136)	1 (137)	0.010 (140)	0.001 (138)	120 (146)	67 (138)	3.4 (136)	7.4 (157)	89 (58)	2.4 (139)	260 (145)	0.05 (143)
Upper Black R. 01-0060-006-02	-	0.7 (136)	135 (136)	2 (136)	0.011 (139)	0.001 (138)	92 (141)	86 (138)	0.3 (135)	7.4 (148)	58 (51)	1.3 (136)	178 (139)	0.02 (141)
Rudder Creek 01-0060-007-02*	-	1.6 (133)	290 (130)	3 (132)	0.930 (130)	0.815 (130)	188 (135)	169 (133)	26.0 (130)	7.6 (139)	48 (48)	1.0 (132)	445 (134)	0.26 (135)
Fox, U/S Lake 01-0060-008-02*	-	0.8 (115)	210 (115)	3 (115)	0.015 (115)	0.003 (113)	135 (115)	67 (115)	1.4 (112)	7.1 (115)	129 (65)	5.5 (115)	276 (115)	0.19 (115)
Cedar Cr, U/S 01-0060-010-02	-	0.7 (77)	110 (78)	1 (78)	0.012 (78)	0.001 (77)	65 (78)	56 (78)	3.7 (77)	7.4 (78)	57 (49)	0.8 (78)	134 (78)	0.02 (77)
Cedar Cr. D/S 01-0060-012-02*	-	1.0 (54)	120 (54)	2 (54)	0.018 (54)	0.003 (54)	70 (54)	59 (54)	5.6 (53)	7.6 (54)	56 (46)	1.0 (54)	163 (53)	0.12 (54)
Little Pic R. 01-0067-001-02	19 (387)	1.4 (69)	160 (81)	35 (593)	0.037 (588)	0.007 (542)	92 (1)	82 (471)	0.0 (68)	8.0 (467)	-	10.0 (67)	167 (566)	0.04 (67)

* Downstream from point source

** Mean monthly discharge (median value)

< Below detection limits

For definition of parameter codes, see Appendix 1.4

APPENDIX 3.1 Cont'd ...

LOCATION:	NNTKUR mg/ℓ	NNO2FR mg/ℓ	NNO3FR mg/ℓ	ACDT mg/ℓ	SSO4UR mg/ℓ	SIO3UR mg/ℓ	NAUR mg/ℓ	DO mg/ℓ	CCNAUR mg/ℓ	CDUT mg/ℓ	COUT mg/ℓ	CUUT mg/ℓ	ZNUT mg/ℓ	PBUT mg/ℓ	NIUT mg/ℓ
North Shore															
White River 01-0057-001-02	0.36 (69)	0.003 (71)	0.01 (71)	3.0 (1)	5.0 (39)	1.9 (124)	1.9 (4)	10.8 (190)	< (3)	< (84)	< (1)	0.001 (144)	0.002 (145)	< (145)	< (15)
Hayward Creek 01-0057-002-02*	6.10 (35)	0.130 (35)	6.05 (20)	6.5 (28)	379.0 (32)	1.6 (35)	72 (35)	8.9 (32)	0.020 (36)	< (35)	0.005 (35)	0.009 (35)	< (35)	< (35)	0.044 (35)
Pic River 01-0060-001-02	0.44 (202)	0.005 (267)	0.04 (477)	4.5 (2)	4.0 (39)	2.1 (66)	1.2 (5)	11.5 (196)	< (3)	< (519)	< (6)	0.004 (500)	0.006 (153)	< (536)	< (21)
Black, Hwy. 17 01-0060-002-02	0.45 (195)	0.005 (261)	0.16 (469)	6.0 (1)	6.8 (36)	2.1 (60)	1.6 (4)	10.9 (184)	< (3)	< (519)	< (4)	0.003 (498)	0.015 (150)	< (534)	< (21)
Black, Hwy. 614 01-0060-003-02	0.46 (138)	0.004 (143)	0.18 (127)	4.0 (148)	15.0 (154)	1.9 (16)	1.1 (19)	11.4 (144)	< (1)	< (134)	< (135)	0.004 (157)	0.028 (157)	< (148)	< (157)
Black, D/S Mose 01-0060-004-02*	1.20 (134)	0.007 (141)	0.17 (126)	5.0 (150)	48.0 (153)	1.6 (18)	2.4 (19)	8.6 (144)	< (1)	< (134)	< (134)	0.007 (155)	0.010 (155)	< (147)	< (154)
Fox, D/S Lake 01-0060-005-02*	0.46 (139)	0.005 (142)	0.13 (126)	5.0 (152)	49.0 (155)	1.0 (17)	3.0 (19)	9.5 (147)	< (1)	0.0010 (135)	< (135)	0.018 (157)	0.352 (157)	< (148)	< (157)
Upper Black R. 01-0060-006-02	0.47 (138)	0.003 (138)	0.05 (123)	5.0 (145)	2.0 (146)	2.6 (12)	0.6 (13)	9.0 (138)	< (1)	< (135)	< (135)	0.001 (148)	0.002 (148)	< 146)	< (148)
Rudder Creek 01-0060-007-02*	1.15 (132)	0.016 (133)	0.31 (118)	8.0 (125)	20.0 (137)	3.4 (6)	8.4 (8)	8.0 (128)	< (1)	< (93)	< (93)	0.004 (100)	0.004 (100)	< (99)	< (100)
Fox, U/S lake 01-0060-008-02*	0.65 (115)	0.008 (115)	0.12 (100)	10.0 (112)	57.0 (115)	-	-	9.1 (109)	-	0.0018 (115)	< (115)	0.021 (115)	0.540 (115)	< (115)	< (115)
Cedar Cr, U/S 01-0060-010-02	0.46 (78)	0.004 (78)	0.06 (62)	5.0 (75)	3.9 (77)	1.6 (34)	2.4 (23)	10.1 (75)	0.001 (74)	< (77)	< (76)	0.001 (77)	< (78)	< (77)	< (77)
Cedar Cr. D/S 01-0060-012-02*	0.73 (54)	0.295 (54)	0.46 (38)	4.0 (46)	7.5 (53)	1.6 (15)	5.8 (2)	10.6 (52)	0.001 (55)	< (53)	< (53)	0.001 (54)	0.001 (54)	< (54)	< (54)
Little Pic R. 01-0067-001-02	0.46 (67)	0.004 (132)	0.004 (359)	-	4.1 (37)	2.1 (121)	1.2 (2)	11.5 (187)	< (3)	< (456)	< (3)	0.003 (495)	0.005 (147)	< (528)	< (18)

APPENDIX 3.1 Cont'd ...

LOCATION:	FEUT mg/ℓ	MNUT mg/ℓ	CRUT mg/ℓ	HGUT µg/ℓ	ASUT mg/ℓ	ALUT mg/ℓ	TCMF cnt/ 100ml	ECIGMF cnt/ 100ml	ECMPN cnt/ 100 ml	FCMF cnt/ 100 ml	PSAMF cnt/ 100 ml
North Shore											
White River 01-0057-001-02	0.14 (46)	< (47)	< (144	< (143)	< (144)	0.06 (5)	160 (68)	-	-	4 (69)	-
Hayward Creek 01-0057-002-02*	0.06 (35)	0.280 (35)	< (35)	0.030 (33)	0.002 (21)	0.06 (37)	-	-	-	-	-
Pic River 01-0060-001-02	0.95 (54)	0.030 (52)	0.002 (149)	< (420)	< (146)	1.56 (10)	100 (136)	-	-	1 (193)	2 (2)
Black, Hwy. 17 01-0060-002-02	0.42 (52)	0.012 (147)	< (147)	< (420)	< (145)	0.40 (6)	70 (129)	-	-	1 (185)	-
Black, Hwy. 614 01-0060-003-02	0.27 (153)	0.023 (150)	< (130)	< (6)	< (69)	0.16 (13)	40 (83)	-	-	0 (138)	-
Black, D/S Hose 01-0060-004-02*	0.44 (153)	0.038 (149)	< (130)	< (5)	< (103)	0.12 (14)	48 (82)	-	-	0 (138)	-
Fox, D/S Lake 01-0060-005-02*	1.20 (155)	0.057 (150)	0.001 (131)	< (4)	< (71)	0.09 (13)	40 (81)	-	-	4 (138)	-
Upper Black R. 01-0060-006-02	0.25 (147)	0.018 (145)	< (131)	< (5)	< (103)	0.12 (14)	73 (80)	-	-	4 (136)	-
Rudder Creek 01-0060-007-02*	0.20 (117)	0.033 (111)	< (92)	< (4)	< (91)	0.09 (6)	1000 (75)	-	-	14 (130)	-
Fox, U/S Lake 01-0060-008-02*	3.00 (113)	0.160 (112)	0.002 (114)	< (1)	< (87)	0.11 (1)	1000 (57)	-	-	90 (112)	-
Cedar Cr, U/S 01-0060-010-02	0.09 (76)	0.012 (76)	< (76)	< (78)	< (75)	0.05 (21)	40 (21)	-	-	0 (74)	10 (10)
Cedar Cr. D/S 01-0060-012-02*	0.10 (54)	0.020 (54)	< (53)	< (54)	< (53)	-	50 (1)	-	-	0 (53)	-
Little Pic R. 01-0067-001-02	1.20 (49)	0.020 (48)	0.002 (147)	< (416)	< (147)	0.98 (9)	154 (66)	-	-	4 (66)	0 (66)

APPENDIX 3.1 Cont'd ...

LOCATION:	Flow** (m^3/s)	BOD$_5$ mg/ℓ	RST mg/ℓ	RSP mg/ℓ	PPUT mg/ℓ	PPO$_4$FR mg/ℓ	HARDT mg/ℓ	ALKT mg/ℓ	CLIDUR mg/ℓ	pH	COLTR TCU	TURB FTU	COND25 uhmos/cm	NNHTFR mg/ℓ
North Shore														
Blackbird Creek 01-0074-001-02*	-	180 (171)	1380 (157)	90 (172)	0.26 (172)	0.010 (16)	122 (91)	119 (135)	272.0 (169)	7.2 (172)	1133 (42)	14.5 (164)	1425 (172)	0.03 (15)
Nipigon River 01-0092-001-02	331 (19)	0.6 (133)	100 (87)	3 (201)	0.008 (196)	0.002 ((196)	70 (3)	72 (170)	< (71)	7.9 (149)	12 (48)	1.5 (148)	145 (156)	0.02 (74)
Black Sturgeon R. 01-0092-001-02	18.8 (154)	1.2 (74)	160 (88)	5 (199)	0.013 (197)	0.002 (197)	70 (1)	59 (165)	20.0 (71	7.7 (200)	-	2.0 (71)	216 (186)	0.02 (71)
Thunder Bay														
Current at 17/11 01-0104-001-02	2.0 (150)	0.8 (225)	75 (164)	1 (201)	0.010 (226)	0.002 (225)	36 (122)	30 (161)	2.0 207)	7.5 (181)	50 (32)	1.3 (185)	76 (223)	0.02 (148)
Current at Cumberland 01-0104-001-02	-	0.8 (207)	75 (141)	1 (159)	0.010 (205)	0.002 (204)	35 (114)	30 (118)	1.9 189)	7.4 (138)	50 (26)	0.88 (168)	73 (205)	0.02 (128)
McVicar Creek 01-0105-001-02	-	0.9 (210)	200 (156)	5 (187)	0.016 (208)	0.003 (208)	124 (109)	93 (146)	16.0 (204)	7.9 (167)	44 (26)	2.8 (168)	264 (208)	0.03 (139)
McIntyre at Hammond 01-0106-001-02*	0.4 (141)	6.0 (181)	190 (125)	15 (166)	0.365 (180)	0.120 182)	98 (72)	83 (115)	18.0 (179)	7.3 (161)	-	9.8 (140)	251 (182)	0.82 (181)
McIntyre at 17 01-0106-002-02	-	0.7 (160)	150 (102)	2 (119)	0.013 (162)	0.003 (160)	88 (99)	76 (99)	8.0 (161)	7.8 (99)	55 (27)	2.4 (161)	185 (164)	0.01 (162)
Neebing at 110 Ave. 01-0107-001-02	0.4 (124)	1.6 (163)	210 (109)	10 (143)	0.040 (164)	0.007 (163)	142 (60)	107 (98)	16.0 (160)	7.4 (120)	-	10.0 (122)	272 (165)	0.11 (166)
Neebing at 17 01-0107-002-02	-	0.8 (199)	190 (144)	4 (154)	0.016 (197)	0.003 (96)	124 (114)	106 (120)	11.0 (193)	7.8 (138)	51 (25)	3.6 (162)	245 (98)	0.03 (198)
Neebing-McIntyre Div. 01-0107-003-02	-	0.9 (47)	180 (47)	4 (47)	0.025 (47)	0.005 (47)	105 (47)	87 (47)	19.5 (46)	7.8 (47)	57 (29)	5.6 (47)	254 (47)	0.06 (46)

APPENDIX 3.1 Cont'd ...

LOCATION:	NNTKUR mg/ℓ	NNO2FR mg/ℓ	NNO3FR mg/ℓ	ACDT mg/ℓ	SSO4UR mg/ℓ	SIO3UR mg/ℓ	NAUR mg/ℓ	DO mg/ℓ	CCNAUR mg/ℓ	CDUT mg/ℓ	COUT mg/ℓ	CUUT mg/ℓ	ZNUT mg/ℓ	PBUT mg/ℓ	NIUT mg/ℓ
North Shore															
Blackbird Creek 01-0074-001-02*	1.70 (172)	0.013 (17)	0.06 (15)	36.0 (98)	80.0 (139)	2.83 (74)	238.5 (8)	3.95 (140)	< (3)	< (50)	< (35)	0.022 (50)	0.084 (49)	< (50)	< (49)
Nipigon River 01-0092-001-02	0.21 (202)	0.002 (203)	0.04 (188)	1.5 (2)	2.0 (38)	1.68 (66)	1.5 (5)	12.2 (192)	< (3)	< (144)	< (2)	0.002 (143)	0.0005 (144)	< (144)	< (15)
Black Sturgeon R. 01-0092-001-02	0.41 (70)	0.004 (71)	0.03 (71)	-	7.7 (37)	3.70 (127)	9.9 (4)	11.6 (187)	< (3)	< (82)	-	0.004 (142)	0.002 (142)	<	< 14
Thunder Bay															
Current at 17/11 01-0104-001-02	0.40 (136)	0.005 (132)	0.03 (128)	3.0 (19)	7.5 (10)	-	-	11.0 (217)	< (3)	< (51)	< (46)	0.002 (52)	0.001 (52)	< (51)	< (52)
Current at Cumberland 01-0104-001-02	0.40 (154)	0.005 (152)	0.03 (143)	3.0 (20)	7.0 (15)	- (34)	- (4)	11.4 (197)	0.005 (1)	< (42)	< (41)	0.001 (43)	0.001 (43)	< (42)	< (43)
McVicar Creek 01-0105-001-02	0.42 (141)	0.006 (140)	0.15 (133)	4.0 (19)	12.0 (16)	4.48 (31)	3.5 (4)	11.4 (199)	< (3)	< (46)	< (41)	0.002 (47)	0.007 (47)	< (46)	< (47)
McIntyre at Hammond 01-0106-001-02*	2.50 (179	0.012 (184)	0.07 (182)	5.0 (5)	18.0 (41)	4.58 (57)	6.0 (5)	8.9 (176)	< (18)	< (65)	< (25)	0.007 (67)	0.011 (67)	0.004 (64)	0.002 (40)
McIntyre at 17 01-0106-002-02	0.42 (161)	0.004 (160)	0.060 (152)	4.0 (19)	-	-	-	11.6 (151)	< (19)	< (45)	< (43)	0.002 (47)	0.001 (47)	< (45)	< (46)
Neebing at 110 Ave. 01-0107-001-02	0.74 (162)	0.008 (163)	0.08 (164)	7.0 (3)	8.5 (16)	6.04 (34)	7.3 (4)	9.5 (155)	< (16)	< (25)	0.001 (17)	0.005 (25)	0.006 (24)	0.003 (24)	0.002 (25)
Neebing at 17 01-0107-002-02	0.52 (197)	0.004 (197)	0.08 (190)	5.0 (19)	10.0 (9)	-	-	10.7 (191)	< (21)	< (44)	< (44)	0.002 (47)	0.002 (47)	< (44)	< (45)
Neebing-McIntyre Div. 01-0107-003-02	0.56 (46)	0.007 (46)	0.15 (37)	4.0 (1)	-	5.80 (4)	12.0 (1)	9.0 (45)	0.001 6)	< (36)	< (36)	0.002 (42)	0.004 (42)	< (36)	< (36)

APPENDIX 3.1 Cont'd ...

LOCATION:	FEUT mg/ℓ	MNUT mg/ℓ	CRUT mg/ℓ	HGUT µg/ℓ	ASUT mg/ℓ	ALUT mg/ℓ	TCMF cnt/ 100ml	ECIGMF cnt/ 100ml	ECMPN cnt/ 100 ml	FCMF cnt/ 100 ml	PSAMF cnt/ 100 ml
North Shore											
Blackbird Creek 01-0074-001-02*	1.40 (134)	0.440 (128)	0.440 (49)	< (110)	0.001 (72)	0.44 (4)	190,000 (161)	0 (1)	-	80 (131)	10 (40)
Nipigon River 01-0092-001-02	0.15 (57)	< (49)	< (142)	< (138)	< (140)	0.11 (3)	4 (140)	-	-	0 (195)	-
Black Sturgeon R. 01-0092-001-02	0.35 (44)	< (46)	< (141)	< (143)	< (142)	0.14 (4)	80 (67)	-	-	1 (67)	-
Thunder Bay											
Current at 17/11 01-0104-001-02	0.40 (58)	0.02 (45)	< (38)	-	< (28)		96 (172)	-	-	4 (174)	0 (16)
Current at Cumberland 01-0104-001-02	0.45 (65)	0.032 (85)	< (47)	< (2)	< (31)	0.12 (3)	100 (184)	-	-	4 (191)	0 (34)
McVicar Creek 01-0105-001-02	0.60 (60)	0.060 (77)	< (42)	0.200 (3)	< (31)	0.10 (3)	1000 (176)	-	-	32 (173)	2 (26)
McIntyre at Hammond 01-0106-001-02*	1.65 (82)	0.100 (77)	0.002 (59)	< (56)	< (62)	0.22 (6)	16000 (176)	-	-	228 (149)	6 (2)
McIntyre at 17 01-0106-002-02	0.55 (65)	0.025 (64)	< (40)	-	< (29)	-	308 (129)	-	-	20 (153)	0 (27)
Neebing at 110 Ave. 01-0107-001-02	1.80 (45)	0.135 (64)	0.001 (18)	< (3)	< (21)	0.28 (4)	1600 (159)	-	-	116 (130)	9 (2)
Neebing at 17 01-0107-002-02	0.80 (77)	0.054 (63)	< (40)	< (1)	< (30)	-	410 (164)	-	-	24 165)	0 (127)
Neebing-McIntyre Div. 01-0107-003-02	0.96 (42)	0.110 (42)	< (35)	< (14)	< (9)	0.10 (10)	900 (17)	-	-	90 (40)	0 (25)

APPENDIX 3.1 Cont'd ...

LOCATION:	Flow** (m^3/s)	BOD_5 mg/ℓ	RST mg/ℓ	RSP mg/ℓ	PPUT mg/ℓ	PPO_4FR mg/ℓ	HARDT mg/ℓ	ALKT mg/ℓ	CLIDUR mg/ℓ	pH	COLTR TCU	TURB FTU	COND25 uhmos/cm	NNHTFR mg/ℓ
Lower Kaministiquia River														
Kam River, Hwy. 61B 01-0108-001-02*	61.3 (210)	9.0 (690)	160 (353)	9 (679)	0.044 (700)	0.008 (693)	45 (148)	36 (496)	11.0 (252)	7.2 (477)	103 (62)	5.7 (253)	157 (54)	0.02 (247)
Kam River, Hwy. 61 01-0108-002-02	-	1.0 (245)	90 (161)	5 (198)	0.016 (247)	0.004 (231)	40 (161)	33 (163)	1.6 (223)	7.4 (175)	66 (52)	3.4 (219)	84 (249)	0.03 (161)
Turning Basin 01-0108-003-02*	-	9.6 (131)	170 (93	10 (102)	0.044 (130)	0.008 (127)	46 (77)	37 (81)	11.5 (126)	7.2 (93)	116 (34)	3.4 (106)	149 (131)	0.03 (89)
Kam River Mouth 01-0108-004-02*	-	2.0 (134)	115 (134)	6 (134)	0.056 (133)	0.006 (130)	49 (133)	45 (133)	7.25 (132)	7.2 (133)	32 (51)	3.8 (134)	130 (134)	0.08 (64)
Kam River at Mission 01-0108-005-02*	58.2 (12)	7.0 (239)	160 (158)	10 (195)	0.046 (237)	0.007 (225)	48 (153)	38 (156)	11.0 (227)	7.1 (168)	96 (64)	5.7 (213)	150 (239)	0.02 (153)
McKellar, 104 Ave. 01-0109-001-02	- -	3.7 (204)	130 (136)	8 (156)	0.062 (203)	0.006 (195)	48 (133)	43 (133)	8.0 (198)	7.1 (133)	68 (55)	5.0 (201)	134 (204)	0.04 (127)
McKellar Mouth 01-0109-002-02	-	2.4 (216)	110 (156)	6 (172)	0.053 (216)	0.006 (212)	49 (139)	44 (144)	6.0 (208)	7.1 (156)	47 (53)	3.8 (189)	125 (215)	0.05 (135)
Mission Mouth 01-0110-001-02	-	6.0 (229)	150 (158)	10 (181)	0.044 (229)	0.007 (220)	46 (141)	39 (145)	10.0 (216)	7.1 (157)	99 (62)	5.3 (204)	148 (229)	0.03 (142)

* Downstream from point source

APPENDIX 3.1 Cont'd ...

LOCATION:	NNTKUR mg/ℓ	NNO2FR mg/ℓ	NNO3FR mg/ℓ	ACDT mg/ℓ	SSO4UR mg/ℓ	SIO3UR mg/ℓ	NAUR mg/ℓ	DO mg/ℓ	CCNAUR mg/ℓ	CDUT mg/ℓ	COUT mg/ℓ	CUUT mg/ℓ	ZNUT mg/ℓ	PBUT mg/ℓ	NIUT mg/ℓ
Lower Kaministiquia River															
Kam River, Hwy. 61B **01-0108-001-02***	0.57 (252)	0.009 (294)	0.02 (634)	5.0 (11)	14.0 (38)	3.36 (56)	6.4 (10)	10.0 (660)	0.001 (20)	< (571)	< (85)	0.004 (580)	0.007 (138)	< (569)	< (80)
Kam River, Hwy. 61 **01-0108-002-02**	0.48 (163)	0.005 (163)	0.04 (148)	2.0 (19)	6.0 (12)	3.40 (3)	1.0 (8)	11.0 (257)	< (24)	< (85)	< (83)	0.003 (136)	0.004 (136)	< (84)	< (89)
Turning Basin **01-0108-003-02***	0.56 (89)	0.008 (91)	0.01 (81)	7.0 (2)	15.0 (5)	5.50 (1)	6.0 (3)	8.0 (128)	-	< (10)	< (10)	0.003 (12)	0.006 (12)	< (11)	< (11)
Kam River Mouth **01-0108-004-02***	0.58 (63)	0.006 (64)	0.24 (48)	7.0 (5)	8.2 (18)	1.20 (1)	6.6 (2)	9.6 (126)	0.0005 (20)	< (88)	< (89)	0.003 (122)	0.005 (122)	< (89)	< (91)
Kam River at Mission **01-0108-005-02***	0.61 (158)	0.008 (160)	0.01 (141)	5.0 (13)	12.5 (12)	3.10 (3)	6.0 (9)	9.1 (228)	< (22)	< (84)	< (84)	0.004 (134)	0.007 (134)	< (84)	< (88)
McKellar, 106 Ave. **01-0109-001-02***	0.68 (126)	0.007 (127)	0.04 (111)	8.0 (7)	-	-	7.0 (1)	8.8 (195)	0.001 (4)	< (79)	< (78)	0.003 (126)	0.005 (126)	< (80)	< (81)
McKellar Mouth **01-0109-002-02***	0.62 (142)	0.006 (141)	0.07 (125)	8.5 (6)	12.0 (3)	-	3.0 (2)	7.9 (205)	< (23)	< (84)	< (83)	0.003 (130)	0.005 (130)	< (84)	< (85)
Mission Mouth **01-0110-001-02***	0.60 (149)	0.008 (150)	0.01 (130)	6.0 (7)	12.5 (4)	3.10 (4)	13.5 (2)	8.8 (220)	< (24)	< (83)	< (82)	0.004 (129)	0.007 (129)	< (83)	< (84)

APPENDIX 3.1 Cont'd ...

LOCATION:	FEUT mg/ℓ	MNUT mg/ℓ	CRUT mg/ℓ	HGUT µg/ℓ	ASUT mg/ℓ	ALUT mg/ℓ	TCMF cnt/ 100ml	ECIGMF cnt/ 100ml	ECMPN cnt/ 100 ml	FCMF cnt/ 100 ml	PSAMF cnt/ 100 ml
Lower Kaministiquia River											
Kam River, Hwy. 61B 01-0108-001-02*	0.63 (141)	0.050 (145)	0.013 (132)	< (556)	< (83)	0.36 (59)	20000 (250)	350 (4)	-	1000 (437)	4 (342)
Kam River, Hwy. 61 01-0108-002-02	0.44 (157)	0.017 (137)	< (67)	< (1)	< (28)	0.18 (55)	190 (237)	-	-	8 (161)	1 (1)
Turning Basin 01-0108-003-02*	0.70 (17)	0.060 (12)	0.010 (13)	-	0.412 (10)	-	26000 (128)	-	-	200 80	-
Kam River Mouth 01-0108-004-02*	0.46 (128)	0.030 (125)	0.003 (91)	-	< (30)	0.12 (52)	6400 (131)	-	-	400 (74)	-
Kam River at Mission 01-0108-005-02*	0.62 (148)	0.049 (134)	0.012 (88)	-	< (29)	0.35 (55)	21000 (231)	-	-	400 (158)	1 (2)
McKellar, 104 Ave. 01-0109-001-02	0.52 (125)	0.036 (124)	0.007 (827)	-	< (11)	0.19 (52)	10300 (199)	-	-	238 (142)	-
McKellar Mouth 01-0109-002-02	0.44 (133)	0.033 (128)	0.005 84)	-	< (30)	0.16 (51)	3900 (211)	-	-	120 (135)	-
Mission Mouth 01-0110-001-02	0.63 (131)	0.050 (126)	0.011 (84)	-	< (29)	0.32 (52)	15000 (225)	-	-	290 (151)	-

APPENDIX 3.2 Median Values for PWQMN stations in the Winnipeg River Drainage Basin

LOCATION:	Flow** (m^3/s)	BOD_5 mg/ℓ	RST mg/ℓ	RSP mg/ℓ	PPUT mg/ℓ	PPO_4FR mg/ℓ	HARDT mg/ℓ	ALKT mg/ℓ	CLIDUR mg/ℓ	pH	COLTR TCU	TURB FTU	COND25 uhmos/cm	NNHTFR mg/ℓ
Wabigoon River														
Dryden U/S 19-0001-005-02	-	0.9 (197)	95 (166)	5 (200)	0.032 (203)	0.013 (201)	49 (129)	47 (125)	1.4 (199)	7.6 (142)	39 (40)	13.0 (172)	105 (203)	0.03 (201)
Dryden D/S 19-0001-006-02*	10.9 (117)	9.2 (200)	220 (169)	15 (200)	0.077 201)	0.019 (192)	62 (128)	56 (125)	25.5 (202)	7.4 (142)	222 (58)	18.0 (172)	234 (203)	0.04 (196)
Minnitaki 19-0001-035-02*	-	2.3 (96)	230 (95)	10 (95)	0.079 (95)	0.017 (93)	76 (96)	63 (96)	37.0 (93)	7.2 (95)	186 (51)	16.0 (95)	284 (96)	0.06 (93)
Near Quibell 19-0001-036-02	27.3 (49)	1.4 (90)	160 (88)	7 (88)	0.051 (89)	0.014 (89)	55 (90)	46 (90)	20.5 (88)	7.3 (89)	115 (49)	9.6 (88)	194 (90)	0.05 (90)
Hwy. 17 19-0001-038-02	-	1.6 (1)	330 (1)	5 (1)	0.095 (1)	0.059 (1)	193 (1)	75 (1)	81.0 (1)	7.3 (1)	256 (1)	11.0 (1)	462 (1)	0.23 (1)
Red Lake Area														
Troutlake River 19-0001-008-02*	-	0.8 (187)	85 (148)	5 (149)	0.027 (187)	0.005 (185)	42 (145)	40 (147)	1.0 (183)	7.5 (145)	46 (37)	4.3 (143)	90 (189)	0.03 (187)
Upper Balmer Creek 19-0001-016-02*	-	1.8 (128)	360 (118)	10 (131)	0.120 (117)	0.058 (118)	142 (98)	66 (101)	40.5 (130)	7.4 (103)	108 (44)	12.0 (130)	505 (134)	1.3 (133)
Lower Balmer Creek 19-0001-032-02*	-	2.0 (123)	340 (109)	5 (123)	0.140 (112)	0.125 (112)	150 (93)	64 (94)	37.0 (123)	7.2 (95)	112 (43)	6.4 (122)	447 (126)	0.39 (123)
Chukuni River 19-0001-015-02	-	0.9 (123)	65 (104)	2 (121)	0.022 (122)	0.008 (122)	28 (92)	25 (92)	1.0 (119)	7.4 (95)	32 (32)	1.5 (119)	66 (126)	0.02 (122)
Bruce Channel 19-0001-018-02	-	0.7 (124	60 (96)	1 (95)	0.015 (124)	0.004 (123)	26 (92)	24 (93)	0.7 (120)	7.4 (96)	35 (33)	0.8 (120)	60 (125)	0.01 (123)
Howey Bay 19-0001-033-02	-	0.8 (126)	60 (95)	1 (93)	0.017 (126)	0.005 (123)	26 (93)	25 (93)	0.8 (121)	7.4 (95)	34 (33)	0.8 (122)	62 (127)	0.02 (124)

* Downstream from point source
** Mean monthly discharge (median value)
< Below detection limits

For definition of parameter codes see Appendix 1.4

APPENDIX 3.2 Cont'd ...

LOCATION:	NNTKUR mg/ℓ	NNO2FR mg/ℓ	NNO3FR mg/ℓ	ACDT mg/ℓ	SSO4UR mg/ℓ	SIO3UR mg/ℓ	NAUR mg/ℓ	DO mg/ℓ	CCNAUR mg/ℓ	CDUT mg/ℓ	COUT mg/ℓ	CUUT mg/ℓ	ZNUT mg/ℓ	PBUT mg/ℓ	NIUT mg/ℓ
Wabigoon River															
Dryden U/S 19-0001-005-02	0.44 (202)	0.006 201)	0.01 (188)	2.0 (7)	3.0 (116)	0.96 (24)	2.0 (3)	10.6 (188)	0.001 (1)	< (10)	0.001 (9)	0.003 (114)	0.004 (128)	0.0005 (10)	< (104)
Dryden D/S 19-0001-006-02*	0.64 (200)	0.012 (195)	0.00 (164)	2.0 (7)	13.0 (116)	1.20 (23)	3.0 (3)	9.0 (184)	-	< (10)	0.0005 (8)	0.005 (116)	0.009 (133)	0.0025 (10)	< (102)
Minnitaki 19-0001-035-02*	0.73 (94)	0.014 (96)	0.02 (73)	-	11.8 (93)	1.30 (21)	-	7.0 (94)	-	.0002 (2)	< (1)	0.004 (96)	0.008 (95)	< (1)	< (94)
Near Quibell 19-0001-036-02	0.59 (88)	0.010 (88)	0.03 (76)	7.4 (88)	-	0.96 (21)	-	9.3 (89)	-	0.0002 (2)	< (1)	0.003 (91)	0.004 (90)	0.003 (1)	< (90)
Hwy. 17 19-0001-038-02	0.80 (1)	0.031 (1)	-	-	19.7 (1)	-	3.8 (1)	-	-	-	-	0.002 (1)	0.005 (1)	-	< (1)
Red Lake															
Troutlake River 19-0001-008-02*	0.46 (186)	0.004 (188)	0.01 (172)	3.0 (102)	3.7 (113)	1.30 (48)	1.0 (3)	10.0 (175)	0.001 (14)	< (76)	< (76)	0.002 (83)	0.003 (78)	< (79)	< (76)
Upper Balmer Creek 19-0001-016-02*	2.70 (133)	0.058 (133)	3.00 (122)	6.0 (101)	74.0 (125)	3.20 (58)	-	8.3 (122)	0.170 (112)	< (99)	0.067 (100)	0.420 (130)	0.150 102)	0.004 (130)	0.575 (102)
Lower Balmer Creek 19-0001-032-02*	1.70 (124)	0.050 (124)	2.50 (113)	8.0 (92)	68.0 (121)	2.40 (55)	-	7.7 113)	0.080 (111)	< (94)	0.040 (94)	0.210 122)	0.066 (95)	0.004 (122)	0.360 (93)
Chukuni River 19-0001-015-02	0.41 (123)	0.003 (123)	0.04 (111)	2.0 (92)	4.6 (116)	0.70 (54)	-	10.0 (114)	0.0005 (108)	< (93)	< (92)	0.005 (122)	0.003 (95)	< (123)	0.005 (94)
Bruce Channel 19-0001-018-01	0.39 (124)	0.002 (125)	0.01 (114)	2 (92)	3.0 (119)	0.80 (56)	-	10.4 (118)	< (108)	< (92)	< (92)	0.002 (124)	0.002 (96)	< (123)	< (93)
Howey Bay 19-0001-003-01	0.38 (125)	0.002 (125)	0.01 (114)	2 (92)	3.3 (118)	0.74 (57)	-	10.1 (114)	< (109)	< (90)	< (91)	0.002 (124)	0.001 (94)	< (124)	< (94)

* Downstream from point source

APPENDIX 3.2 Cont'd ...

LOCATION:	FEUT mg/ℓ	MNUT mg/ℓ	CRUT mg/ℓ	HGUT µg/ℓ	ASUT mg/ℓ	ALUT mg/ℓ	TCMF cnt/ 100ml	ECIGMF cnt/ 100ml	ECMPN cnt/ 100 ml	FCMF cnt/ 100 ml	PSAMF cnt/ 100 ml
Wabigoon River											
Dryden U/S 19-0001-005-02	0.81 (121)	0.016 (115)	0.003 (6)	< (122)	< (52)	0.90 (2)	69 (168)	-	-	1 (102)	-
Dryden D/S 19-0001-006-02*	0.94 (120)	0.071 (116)	0.010 (6)	0.009 (120)	< (52)	1.04 (2)	300,000 (171)	-	-	340 (104)	-
Minnitaki 19-0001-035-02*	0.87 (95)	0.067 (95)	0.010 (1)	0.021 (87)	< (45)	0.96 (1)	62000 (88)	-	-	380 (45)	-
Quibell 19-0001-036-02	0.63 (91)	0.046 (1)	0.006 (1)	0.017 (82)	< (42)	0.48 (1)	3500 (85)	-	-	36 (43)	-
Hwy. 17 19-0001-038-02	0.47 (1)	0.096 (1)	-	0.012 (22)	-	-	30,000 (1)	-	-	-	-
Red Lake											
Troutlake River 19-0001-008-02*	0.35 (134)	0.013 (67)	< (35)	< (80)	0.002 (83)	0.06 (9)	16 (85)	-	-	< (95)	-
Upper Balmer Creek 19-0001-016-02*	0.88 (103)	0.170 (128)	0.003 (2)	0.070 (120)	0.610 (128)	1.40 (1)	66 (84)	-	-	< (115)	
Lower Balmer Creek 19-0001-032-02*	0.77 (97)	0.150 (119)	0.001 3	0.045 (110)	0.500 (121)	1.30 (1)	1100 (78)	-	-	10 (114)	
Chukuni River 19-0001-015-02	0.11 (97)	0.009 (119)	< 3	< (114)	0.017 (122)	0.20 (1)	29 (74)	-	-	0 (107)	-
Bruce Channel 19-0001-018-01	0.09 (96)	0.005 (118)	0.001 3	< 114	0.008 123	0.08 1	12 (63)	-	-	0 (98)	-
Howey Bay 19-0001-033-01	0.07 (96)	0.005 (118)	0.002 (2)	< 110	0.007 121	-	16 (76)	-	-	0 (111)	-

APPENDIX 3.2 Cont'd ...

LOCATION:	Flow** (m^3/s)	BOD$_5$ mg/ℓ	RST mg/ℓ	RSP mg/ℓ	PPUT mg/ℓ	PPO$_4$FR mg/ℓ	HARDT mg/ℓ	ALKT mg/ℓ	CLIDUR mg/ℓ	pH	COLTR TCU	TURB FTU	COND25 uhmos/cm	NNHTFR mg/ℓ
Rainy River														
U/S Fort Frances 19-0001-004-02	256.0 (144)	0.7 (236)	55 (180)	3 (230)	0.018 (236)	0.004 (228)	22 (153)	19 (174)	1.0 (223)	7.3 (178)	37 (33)	1.6 (177)	54 (232)	0.02 (182)
D/S Fort Frances 19-0001-012-02*	-	1.2 (196)	70 (145)	5 (189)	0.030 (199)	0.006 (195)	26 (112)	22 (120)	3.0 (185)	7.3 (121)	51 (34)	2.8 (160)	66 (188)	0.02 (142)
U/S Emo 19-0001-011-02	-	1.0 (202)	80 (147)	6 (195)	0.036 (201)	0.008 (196)	32 (115)	28 (119)	3.0 (190)	7.3 (120)	59 (39)	3.9 (165)	77 (193)	0.02 (144)
D/S Emo 19-0001-003-02*	-	1.0 (206)	80 (151)	7 (195)	0.037 (205)	0.008 (203)	31 (120)	27 (120)	3 (195)	7.3 (128)	57.5 (38)	3.9 (164)	75 (199)	0.03 (149)
U/S Baudette 19-0001-010-02	-	1.0 (201)	85 (147)	5 (192)	0.034 (200)	0.008 (194)	40 (117)	34 (127)	3 (189)	7.4 (128)	68 (40)	3.4 (159)	90 (192)	0.03 (142)
D/S Baudette 19-0001-009-02*	-	1.0 (220)	88 (164)	6 (214)	0.036 (217)	0.008 (213)	38 (119)	33 (132)	3 (205)	7.4 (134)	63 (37)	3.6 (172	87 (213)	0.03 (162)
Winnipeg River														
Kenora U/S 19-0001-001-02	-	0.7 (204)	90 (173)	2 (204)	0.023 (202)	0.006 (201)	54 (149)	49 (144)	2.3 (200)	7.7 (161)	23.5 (50)	1.6 (177)	117 (203)	0.02 (154)
Kenora D/S 19-0001-002-02*	-	2.5 (206)	100 (173)	4 (206)	0.028 (205)	0.003 (202)	54 (151)	49 (146)	2.6 (202)	7.4 (162)	27 (51)	2.8 (178)	122 (205)	0.01 (157)

APPENDIX 3.2 Cont'd ...

LOCATION:	NNTKUR mg/ℓ	NNO2FR mg/ℓ	NNO3FR mg/ℓ	ACDT mg/ℓ	SSO4UR mg/ℓ	SIO3UR mg/ℓ	NAUR mg/ℓ	DO mg/ℓ	CCNAUR mg/ℓ	CDUT mg/ℓ	COUT mg/ℓ	CUUT mg/ℓ	ZNUT mg/ℓ	PBUT mg/ℓ	NIUT mg/ℓ
Rainy River															
U/S Fort Frances 19-0001-004-02	0.40 (140)	0.004 (141)	0.02 (141)	2.0 (84)	6.0 (73)	1.31 (56)	2.0 (62)	10.0 (225)	0.001 (17	< (49)	< (49)	0.002 (79)	0.002 (81)	< (49)	< (77)
D/S Fort Frances 19-0001-012-02*	0.47 (102)	0.004 (101)	< (101)	3.0 (58)	7.0 (14)	1.49 (8)	2.0 (8)	9.2 (189)	0.001 (15)	< (48)	< (48)	0.002 (49)	0.002 (49)	< (48)	< (48)
U/S Emo 19-0001-011-02	0.57 (103)	0.005 (103)	< (100)	3.0 (61)	8.0 (15)	1.73 (11)	2.0 (10)	9.0 (192)	0.0005 (14)	< (48)	< (48)	0.003 (49)	0.012 (49)	< (47)	< (47)
D/S Emo 19-0001-003-02*	0.57 107	0.005 108	< 105	3 (60)	7.0 (17)	1.96 (10)	2.0 (13)	9.0 (196)	-	< (23)	< (23)	0.002 (24)	0.001 (24)	< (23)	< (23)
U/S Baudette 19-0001-010-02	0.60 (100)	0.006 (101)	0.01 96	3 (52)	7.5 (18)	1.87 (11)	2.0 (12)	9.0 (189)	0.001 (1)	< (22)	< (22)	0.002 (23)	0.003 (24)	< (22)	< (22)
D/S Baudette 19-0001-009-02*	0.58 (120)	0.006 (121)	0.01 (115)	3 (52)	8.0 (23)	1.75 (16)	2 (17)	9.4 (213)	0.001 (15)	< (49)	< (49)	0.002 (51)	0.004 (53)	< (49)	< (49)
Winnipeg River															
Kenora U/S 19-0001-001-02	0.49 (151)	0.003 (154)	0.04 (142)	1.5 (8)	39.5 (2)	1.10 (53)	2.0 (3)	10.0 (196)	-	< (54)	< (54)	0.002 (120)	0.001 (133)	< (54)	< (54)
Kenora D/S 19-0001-002-02*	0.57 (155)	0.003 (157)	0.01 (144)	2 (7)	15 (2)	1.10 (64)	2.0 (3)	9.5 (194)	-	< (54)	< (54)	0.002 (120)	0.003 (137)	< (54)	< (55)

APPENDIX 3.2 Cont'd ...

LOCATION:	FEUT mg/ℓ	MNUT mg/ℓ	CRUT mg/ℓ	HGUT µg/ℓ	ASUT mg/ℓ	ALUT mg/ℓ	TCMF cnt/ 100ml	ECIGMF cnt/ 100ml	ECMPN cnt/ 100 ml	FCMF cnt/ 100 ml	PSAMF cnt/ 100 ml
Rainy River											
U/S Fort Frances 19-0001-004-02	0.19 (93)	0.007 (76)	< (47)	< (66)	< (28)	0.11 (39)	140 (201)	-	-	1 (146)	4 (1)
D/S Fort Frances 19-0001-012-02*	0.20 (53)	0.011 (46)	< (45)	< (67)	< (27)	0.06 (10)	4200 (171)	-	-	400 (124)	-
U/S Emo 19-0001-011-02	0.30 (51)	0.018 (43)	0.0005 (46)	< (62)	< (28)	0.08 (9)	3800 (174)	-	-	200 (130)	1 (1)
D/S Emo 19-0001-003-02*	0.27 (44)	0.014 (26)	< (23)	< (39)	< (1)	0.065 (6)	2700 (181)	-	-	190 (129)	-1 (1)
U/S Baudette 19-0001-010-02	0.30 (39)	0.017 (30)	< (22)	< (39)	-	0.065 (4)	1300 (173)			40 (123)	1 (1)
D/S Baudette 19-0001-009-02*	0.04 (56)	0.020 (46)	- (46)	< (66)	< (27)	0.120 (9)	1500 (195)	-	-	60 (146)	4 (1)
Winnipeg River											
Kenora U/S 19-0001-001-02	0.10 (127)	0.009 (120)	< (52)	< (3)	< (55)	3.1 (1)	170 (186)	-	-	8 (113)	-
Kenora D/S 19-0001-002-02*	0.12 (129)	0.012 121	< (50)	< (3)	< (55)	3.8 (1)	4350 (188)			149 (114)	